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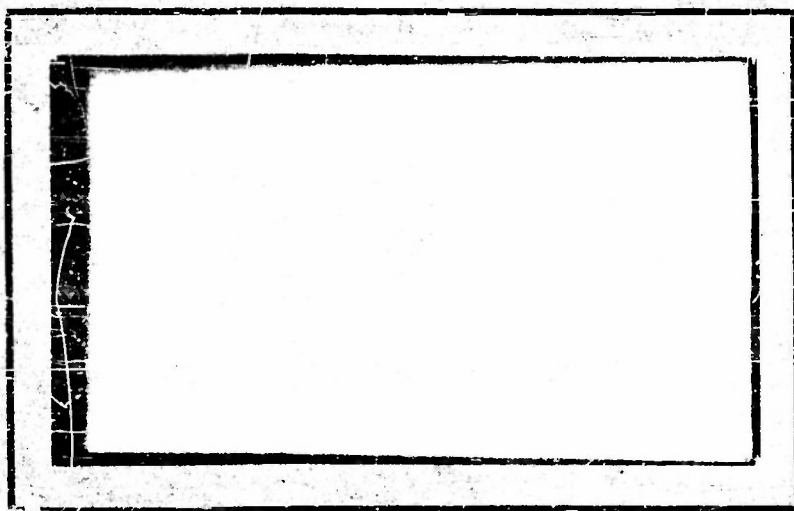
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World Gravity Measurements

1952 - 1954

By

George P. Woollard

William A. Black

William E. Bonini

Technical Report

Submitted to Geophysics Branch, Office of Naval Research
Under Contract N6onr-27704 (NR-081-091)

July 1954

APPROVED FOR DISTRIBUTION


Director

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1952 - 1954

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WORLD GRAVITY MEASUREMENTS

1952 - 1954

by

G.P. Woollard, W.A. Black, W.E. Bonini

PREFACE

This report is the most recent of a series covering gravity observations carried out on a global basis by the Woods Hole Oceanographic Institution under contract N6 onr-27704(NR-081-091) with the Office of Naval Research of the U.S. Navy. To date the following reports and publications have been released in connection with this investigation.

*Woods Hole Oceanographic Institution Memorandum, Report on Field Tests on Special Worden Gravity Meter, Aug. 16, 1948.

*Woods Hole Oceanographic Institution Technical Report 49-33, World Wide Gravity Measurements with a Gravity Meter, July 15, 1949.

The Gravity Meter as a Geodetic Instrument, Woollard, G.P. Geophysics, Vol. 15, No. 1, pp. 1-29, 1950. This publication includes all the results given in the preceding references.

*Woods Hole Oceanographic Institution Technical Report 52-59, World Wide Gravity Observations conducted during the period June 1949 - January 1952.

Woods Hole Oceanographic Institution Technical Report 53-66, Status of World Wide Gravity Measurements, August, 1953.

* These reports are now out of print

A companion report to the above series covering pendulum and gravity meter work done under the auspices of the Cambridge Research Center of the U.S. Air Force is Woods Hole Oceanographic Institution Technical Report 53-36, A Study of Methods for Measuring Large Changes in Gravity on an Inter-continental Basis. This report, based upon gravity studies made between Mexico and Alaska, deals with the problem of standardization of gravity values and errors of measurement. It also includes results for an extended series of measurements in Mexico, the United States, Canada and Mexico.

ABSTRACT

The results of gravimeter observations carried out during the period January, 1952 - May, 1954 are presented. Gravity values and descriptions of new observation sites are reported for South and Central America, the Canadian Arctic and Europe. Comparative values, as obtained by other investigators are given for points of common measurement. Corrected values are given for earlier observations made under this program in Central and South America where the later more complete studies indicate changes are in order because of differences in calibration standard used or tares not detected in the original work. Results for approximately 2000 observations are included.

INTRODUCTION

General Statement on Gravity Program

This report covers the most recent of a series of gravity observations that have been carried out on a world wide basis since 1948 with high range geodetic type gravimeters. The initial phase of the program was a test of the feasibility of using gravimeters for making long distance gravity ties involving large changes in gravity, and the establishment of the relative accuracy with which such observations could be made and repeated. Since the completion of this part of the program, the general plan has been (1) to establish inter-continental networks of gravity stations on a global basis both for control purposes and the detection of errors in international gravity bases that are now being used, and (2) to develop and extend existing gravity networks in the various continents.

Although several attempts were made prior to 1947, by the writer as well as others, to use gravimeters for making gravity observations on an inter-continental basis, these attempts were, for the most part, unsuccessful. This was because of the difficulty of determining instrumental drift (changes in instrument reading with time) while in transit, and the difficulty of maintaining the instruments at constant temperature during the period of the observational program. It was not until the development of a few high range "driftless", constant temperature gravimeters and the small temperature compensated, high range Worden gravimeter, that a world program of gravimeter measurements became possible.

Accuracy of Measurements

Although the apparent accuracy of the original measurements made under this program (Woodward, 1950) was better than one mgal ($.001 \text{ cm/sec.}^2$), there was some question concerning the accuracy

of values taken at high latitudes since there was no suitable method of obtaining an overall calibration of the gravimeter. This problem is now believed to be nearing a solution, and an accuracy of better than one mgal soon should be obtainable everywhere. The present accuracy of gravimeter measurements between points lying in the same general latitude belt appears to be approximately 0.2 to 0.3 mgal. These figures are based on comparisons between gravimeter values and recent pendulum gravity measurements carried out by the Woods Hole Oceanographic Institution, the U.S. Coast and Geodetic Survey and the Dominion Observatory of Canada. On these measurements, the Woods Hole group used the quartz pendulums of the Gulf Research Development Co. The Dominion Observatory used the invar pendulums of Cambridge University, England, compensated for changes in the earth's magnetic field by the use of a Helmholtz coil, and the U.S. Coast and Geodetic Survey used the Brown invar pendulums with similar magnetic compensation. Separate reports covering these pendulum measurements are now in preparation and should be released shortly.

Status of Observational Program

The primary network of gravity stations established to date consists of a closed loop around the world, with subsidiary networks of stations in each continent. The world-girdling loop was first run in 1948, and the same series of stations "leap-frogged" * out again in 1950. This loop of stations serves as a base line to which the subsidiary continental networks of stations, developed under this program in North America, South America, Europe, Africa, Australia and Asia, are tied. This year, key points on the world loop and in each of the continental networks are being reoccupied on a "leap-frog" basis with two Worden gravimeters, and these measurements should materially strengthen the values.

Changes in Gravity Values Originally Reported

The gravimeter used in carrying out the initial phase of this program in 1948 and 1949 was calibrated against the gravity values adopted for the various national gravity bases occupied; namely Greenwich, Paris, Copenhagen, Stockholm, DeBilt, Helsinki, Rome, Tokyo, Ottawa and Washington. Subsequent comparative studies against series of pendulum observations in various parts of the world showed

* "Leap-frog": Observations made following a sequence in which each station is double tied to the preceding and following stations by repeat observations.

that a better calibration could be obtained by using the Cambridge University (England) pendulum values as obtained in Australia and Great Britain. With the release of this report, all values previously reported will have been adjusted to this standard. However, there is still some question regarding the adjustment of the original work and also some uncertainty concerning the degree to which magnetic compensation had been achieved on these Cambridge pendulum measurements that are being used as a calibration standard. It is therefore possible that further adjustment of values will be necessary upon the completion of the reductions for the pendulum studies conducted between Mexico and Alaska referred to earlier, and upon completion of this summer's gravimeter program.

Work Included in Report

Most of the present report is devoted to gravity observations in South America, but results for three other series of measurements are also included. In addition to the new work reported, the earlier observations made in South America by N.C. Harding in 1949 have been revised to conform to the Cambridge pendulum calibration standard which was adopted in 1950. Although in some places the correction for this change in calibration amounts to 4.0 mgals, the agreement obtained between the old observations after this adjustment and new observations taken at the same sites in 1952, on the average, is better than ± 0.4 mgal.

RESULTS 1953 PROGRAM

Comparative Measurements with Different Type Gravimeters

In 1952, a series of comparative measurements were conducted between the Commerce Building national gravity base in Washington, D.C. and the National Physical Laboratory, Teddington, England, using a new Worden high range temperature compensated gravimeter (W 126) and a Frost, high range, constant temperature, "driftless" gravimeter. These instruments were made available for these tests by Ohio State University and Columbia University respectively. In order to obtain valid comparisons, both meters were indirectly calibrated against the Cambridge pendulum standard through comparisons at bases established with gravimeter W 10e.

Although the Frost meter did actually drift during the first day of the observations, there was no subsequent indication of any change in reading with time at any of the sites occupied. The overall closure, including the observed drift, was 0.8 scale division for the 10 day period of the tests. The observations were carried out as a closed loop from Washington and most of the key stations occupied on the out-going leg were reoccupied on the return leg of the trip. Observations were made at the locations listed in Table I, and the intervals of gravity measured varied from 20.0 mgals to 2362.0 mgals.

Table I

Observation Sites with Frost and Worden Meters

Lamont Geological Observatory, Palisades, New York
Princeton University, Princeton, New Jersey
Department of Commerce National Gravity Base, Washington, D.C.
Naval Air Station, Patuxent, Maryland
Naval Air Station, Argentia, Newfoundland
Blackbushe Royal Air Force Base, England
U.S. Naval Headquarters, Grosvenor Square, London, England
National Physical Laboratory, Teddington, England
Pendulum House, Cambridge University Observatory, Cambridge, England
Orly Air Force Base, Paris, France
Fleet Naval Air Terminal, Naples, Italy
Naval Air Station, Port Lyautey, French Morocco
Lagens Air Force Base, Terceira, Azores
Gander Airport, Newfoundland

Most of the above stations had been occupied previously with various Worden meters in connection with the world gravity program, and they were again occupied in January, 1954 with Worden meters 10f and 147; the latter two meters probably being the best of this type built to date. These comparisons therefore serve two purposes: (1) to determine if there are any significant differences in values obtained with a "driftless" meter as compared to one having pronounced drift as the temperature compensated Worden meters; (2) to show the degree of agreement obtained between the early measurements using the first high range Worden meter and modern, improved high range Worden meters.

In Table II, the comparative results are given along with departures from the mean values, and these differences are shown graphically in Fig. 1.

Table II

Comparative Gravity Values
Obtained with Different Type Gravity Meters

(Calibration standard used: Australian and British Cambridge pendulum values.)

Madison, Wisconsin

University of Wisconsin, Science Hall Basement, Room 7.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10c	1949	980.3677	-0.8 mgals
Worden 41b	1950	.3681	-0.4
		.3684	-0.1
Worden 10e	1950	.3683	-0.2
		.3685	0.0
Worden 10e	1951	.3686	+0.1
		.3681	-0.4
Worden 10e	1952	.3685	0.0
		.3683	-0.2
Frost	1952	.3685	0.0
Worden 142	1952	.3685	0.0
Worden 10f	1953	.3686	+0.1
Worden 147	1953	.3686	+0.1
Worden 10f	1954	.3685	0.0
Worden 147	1954	.3685	0.0
Mean Value		980.3685	

Patuxent, Maryland

Naval Air Station, Fleet Air Wing Terminal.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10a	1948	980.0262	+0.3
Worden 41b	1950	.0258	-0.1
Worden 10e	1950	.0259	0.0
Worden 10e	1951	.0262	+0.3
		.0259	0.0
Frost	1952	.0265	+0.6
Worden 126	1952	.0254	-0.5
Worden 10e	1953	.0261	+0.2
Worden 10f	1954	.0256	-0.3
Worden 147	1954	.0257	-0.2
Mean Value		980.0259	

Table II

Argentia, Newfoundland

Naval Air Station, Coast Guard Hangar on lower level.
Old Fleet Air Wing terminal.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 41b	1950	980.8549	+0.3 mgals
Worden 10e	1951	.8543	-0.3
		.8546	0.0
Frost	1952	.8565	+1.9
Worden 126	1952	.8545	-0.1
Worden 10e	1953	.8546	0.0
Worden 142	1953	.8549	+0.3
Worden 10f	1954	.8546	0.0
Worden 147	1954	.8548	+0.2
Mean Value		980.8546	

Terciera, Azores

Lagens Air Force Base Terminal.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10b	1948	980.1760	-0.1 mgals
Worden 41b	1950	.1759	-0.2
Worden 10e	1951	.1761	0.0
		.1764	+0.3
Frost	1952	.1770	+0.9
Worden 126	1952	.1762	+0.1
Worden 10e	1953	.1763	+0.2
Worden 10f	1954	.1760	-0.1
Worden 147	1954	.1758	-0.3

London, England

U.S. Naval Headquarters, Grosvenor Square.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10b	1948	981.2001	0.0 mgals
Worden 10e	1951	.2000	-0.1
		.2003	+0.2
Frost	1952	.2002	+0.1
Worden 126	1952	.2001	0.0
Worden 10e	1953	.2001	0.0
Worden 142	1953	.2001	0.0
Worden 10f	1954	.2003	+0.2
Worden 147	1954	.2005	+0.4
Mean Value		981.2001	

Table II

Teddington, England

National Physical Laboratory, Meteorology Building.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10b	1948	981.1961	0.0 mgals
Worden 10e	1951	.1960	-0.1
		.1960	-0.1
Frost	1952	.1962	+0.1
Worden 126	1952	.1960	-0.1
Worden 10e	1953	.1961	0.0
Worden 10f	1954	.1964	+0.3
Worden 147	1954	.1966	+0.5
Mean Value		981.1961	

Cambridge, England

Pendulum House on grounds of Astronomical Observatory.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10b	1948	981.2684	+0.2 mgals
Worden 10e	1951	.2681	-0.1
		.2679	-0.3
Frost	1952	.2684	+0.2
Worden 126	1952	.2679	-0.3
Mean Value		981.2682	

Port Lyautey, French Morocco

Naval Air Station, old terminal.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10b	1948	979.6531	+1.0
Worden 41b	1950	.6519	-0.2
Worden 10e	1951	.6525	+0.4
Frost	1952	.6505	-1.6
Worden 126	1952	.6525	+0.4
Worden 10f	1954	.6519	-0.2
Worden 147	1954	.6520	-0.1
Mean Value		979.6521	

Table II

Naples, Italy

Capodichino Airport, Fleet Air Wing Terminal.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Frost	1952	980.2575	+0.5 mgals
Worden 126	1952	.2572	+0.2
Worden 10f	1954	.2568	-0.2
Worden 147	1954	.2556	-0.4
Mean Value		980.2570	

Blackbushe, England

Royal Air Force Base terminal.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Frost	1952	981.1550	0.0
Worden 126	1952	.1552	+0.2
Worden 10e	1953	.1552	+0.2
Worden 142	1953	.1548	-0.2
Mean Value		981.1550	

Palisades, New York

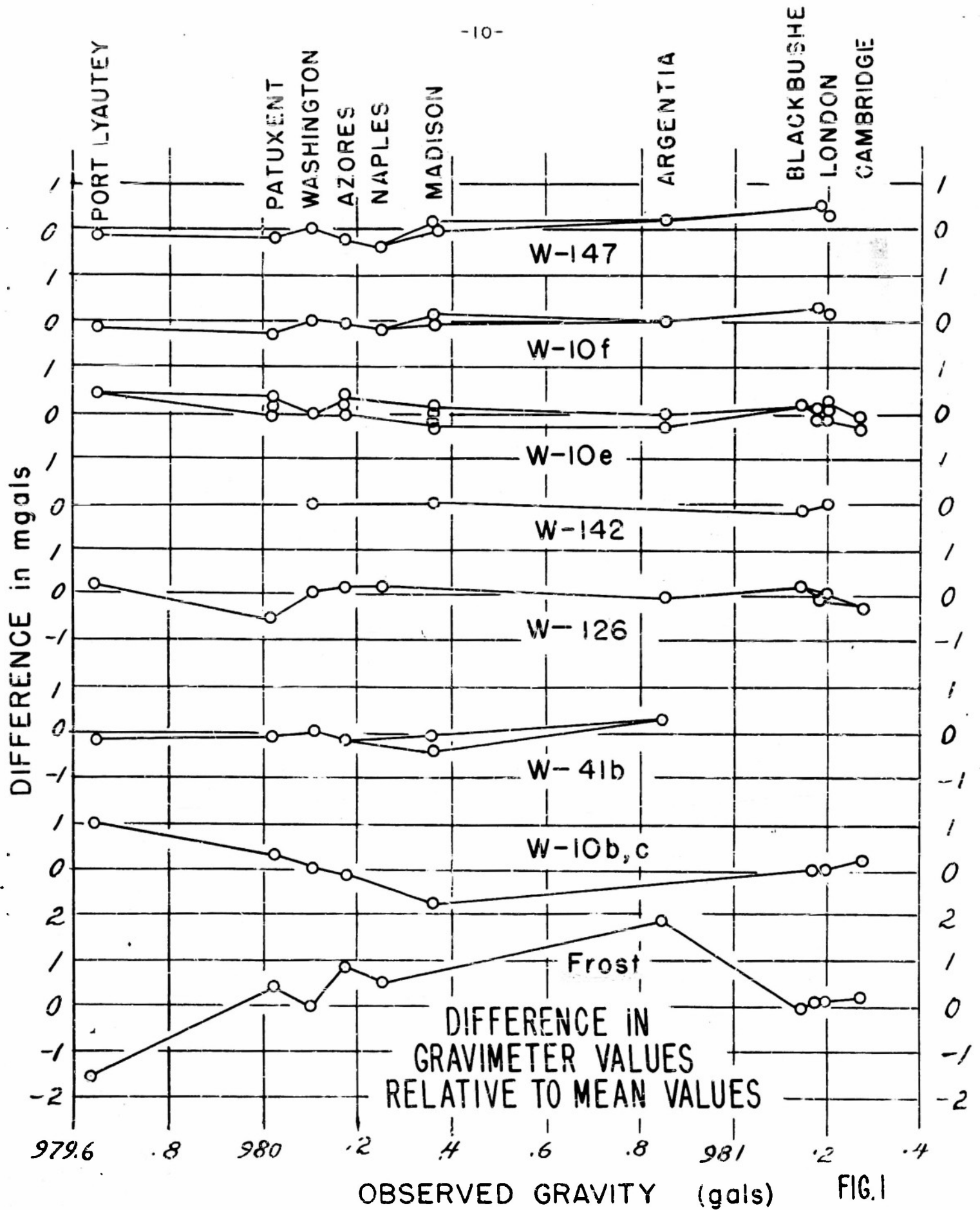
Lamont Geological Observatory.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Worden 10c	1949	980.2583	-1.1
Frost	1952	.2607	+1.3
		.2597	+0.3
North American	1952	.2593	-0.1
Worden 10e	1952	.2591	-0.3
Mean Value		980.2594	

Princeton, New Jersey

Guyot Hall, Princeton University.

<u>Meter</u>	<u>Year</u>	<u>Observed Gravity</u>	<u>Departure from Mean</u>
Frost	1952	980.1789	-0.3
Worden 10e	1953	.1802	+0.7
Mean Value		980.1795	

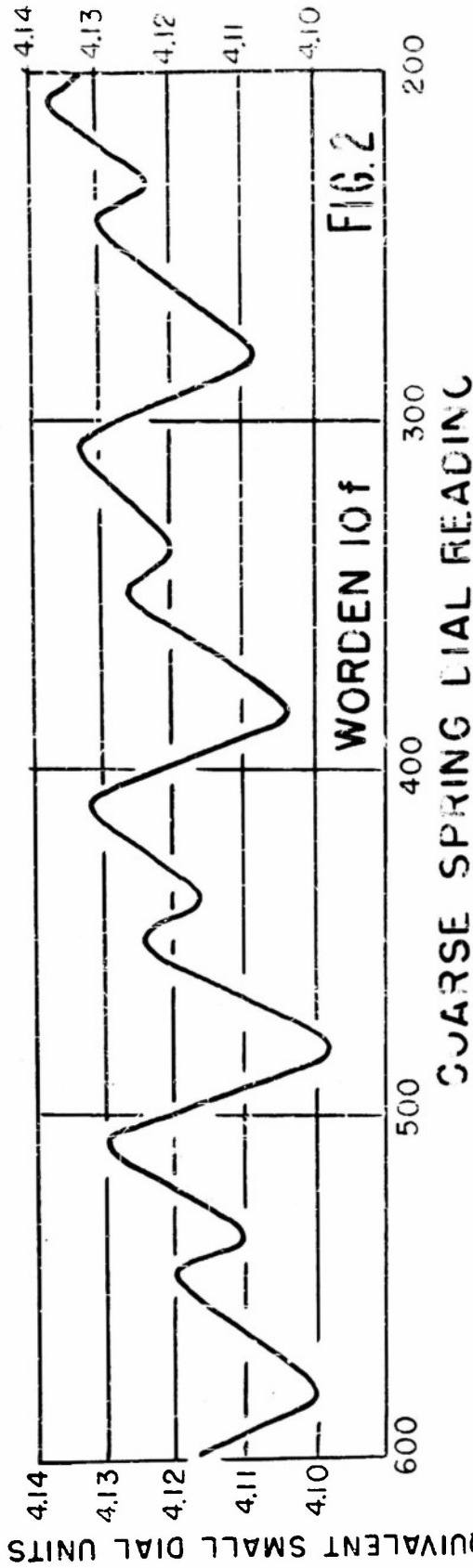


Remarks on Test

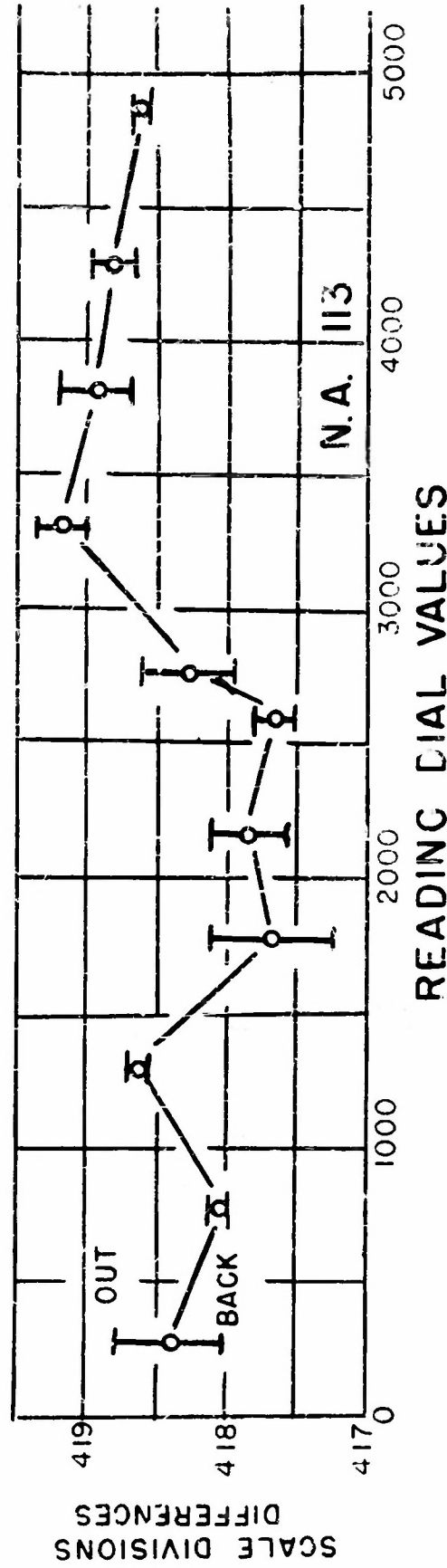
As seen from Table II and Fig. 1, the Worden meters gave better agreement with each other than was obtained with the Frost meter. As the differences in results observed with the Frost meter showed no dependence upon either time or the gravity interval, and as the values obtained at the stations reoccupied on the return leg agreed within 0.2 mgals of those observed on the outgoing leg, the differences do not appear to be related to faulty readings or temperature or pressure effects. The Worden meters were of widely different ranges (3500 mgals to 6000 mgals) with entirely different drift rates and reading sensitivity values. The differences therefore appear to be related to some idiosyncrasy of the Frost meter peculiar to certain portions of its scale.

This idiosyncrasy factor connected with individual instruments has not received as much attention as it deserves. This has been largely because, as a rule, it is appreciable only in high range gravimeters; and further, it is not apt to be detected even with these instruments unless special tests are conducted. On the Worden meters which have two spring systems with independent reading dials, the response of the principal high range spring can be evaluated in terms of the more sensitive low range spring and any reading idiosyncrasy of the instrument can be easily determined. Fig. 2, for example, shows the change in the equivalent low range (fine) spring dial values for changes in setting of the high range (coarse) spring dial for Worden meter 102. The apparent "wobble" for the large spring reading dial shown is not peculiar to Worden instruments, but is one that is believed to be present in all high range gravimeters. From tests conducted by the writers and the manufacturers of the Worden instruments, it appears that the "wobble" is derived from three sources: (1) variations in the pitch of the screw connecting the spring to the reading dial; (2) inaccuracies in the spacing of dial head division markers; and (3) eccentric setting of the dial head on the screw shaft.

On instruments such as the North American, Frost and Western high range gravimeters which have a single reading dial, it is not always obvious that such effects are present. Yet, if the interval covering a large change in gravity is checked for the dial reading difference for a series of reset positions covering the range of the instrument, it is found that there are indications of similar systematic variations. The results for such a test showing this effect with a North American high range gravimeter is shown in Fig. 3. That this observed anomalous response associated with the reading dial may lead to systematic errors has been indicated by recent tests conducted by the Houston Technical Laboratory.



ANOMALOUS VARIATIONS OF COARSE SPRING DIAL READING



VARIATIONS IN SCALE DIFFERENCES FOR 100 MGAL INTERVAL AT
DIFFERENT RESET POSITION OF READING DIAL

According to HARDING (1954), if a calibration is started at a dial reading corresponding to the beginning of the observed anomalous response curve, Point A of the curve shown in Fig. 4, then the mean error curve would average a consistently positive value as indicated by the dashed curve A shown in Fig. 4. The resulting average calibration would be too high. However, if the calibration is started at a dial reading point corresponding to Point B, the mean error curve would average about zero as is indicated by dashed curve B in Fig. 4. The average calibration value determined under these conditions would be essentially correct. If the calibration is started at a point corresponding to Point C on the observed anomalous response curve, the mean error curve would follow dashed curve C and the resulting calibration would be too low.

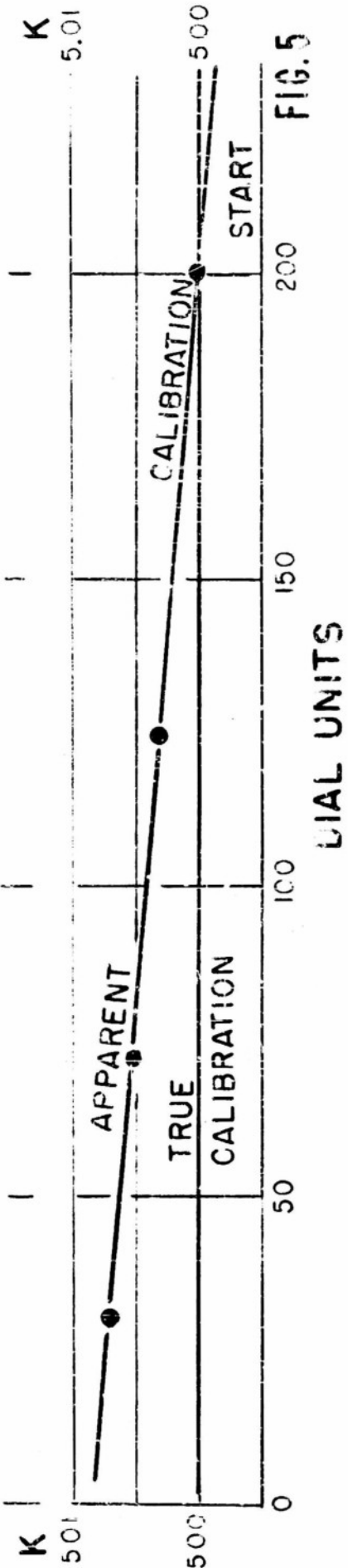
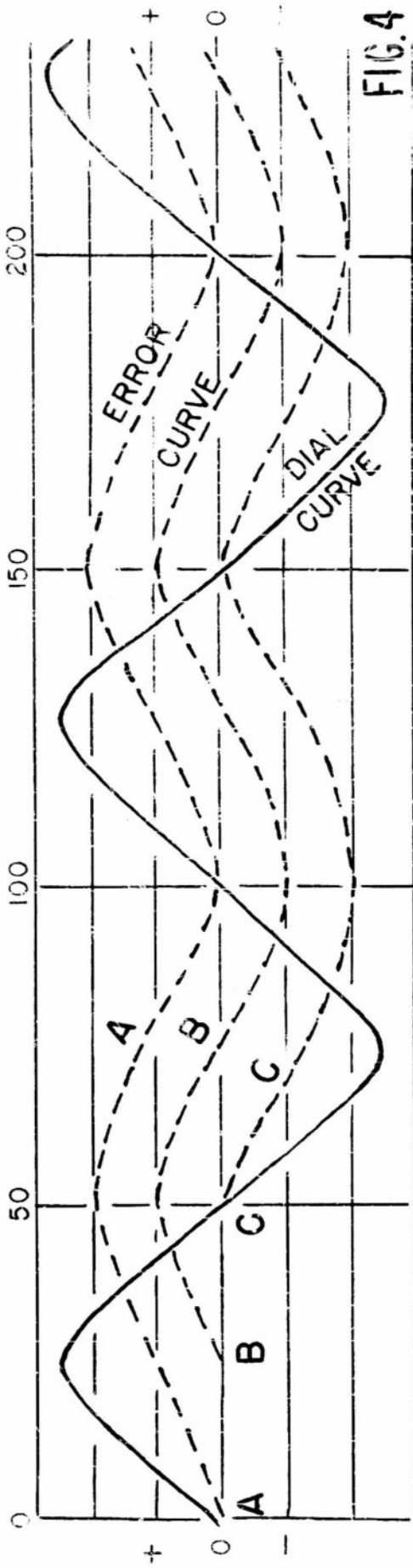
An example of this effect on the tilt table calibration for a Worden gravimeter, when starting the calibration at a dial reading corresponding to Point A on the anomalous response curve of the dial, is shown in Fig. 5. Compared to the true calibration, the apparent calibration, when established under this condition, is both too high and also indicated a fictitious non-linearity. The importance of these effects naturally depends upon the range in gravity covered by a revolution of the reading dial. The greater the equivalent change in gravity per revolution, the more important the effect.

To eliminate errors in calibration having this origin, the following procedure has been adopted by the writers: (1) determine the anomalous response for the coarse spring dial by establishing the equivalent number of fine spring dial units per coarse dial unit by actual field measurements at a sufficient number of places to cover the range of the instrument; (2) integrate this curve so that any difference in coarse spring dial units can be equated to an equivalent number of fine spring dial units; (3) establish the calibration in terms of the fine spring dial units. Using this system, all reductions in values for establishing an observed value of gravity is done entirely in terms of the equivalent fine spring dial units. As any screw or dial effect connected with the fine spring is of negligible importance, the resulting values are essentially correct.

Arctic Observations

In the spring of 1952, arrangements were made through the U.S. Weather Bureau to have an observer make gravity observations at the various advance arctic weather stations at the time of the spring resupply flights. Observations were made in Canada at Montreal, Quebec; Churchill, Manitoba; Resolute Bay, Mould Bay, Isachsen and Alert, Northwest Territory; and at Thule, Greenland.

RELATION MEAN ERROR TO DIAL CURVE



EFFECT OF DIAL CURVE ON CALIBRATION CURVE STARTING AT A

Unfortunately, a closure could not be affected on this survey. This resulted from a return trip being made inadvertently on a non-stop flight from Thule, Greenland to Westover Air Force Base, Massachusetts, and the gravity interval involved exceeded the range of the instrument being used. These stations were reoccupied again in April, 1954 under the auspices of the Air Force Cambridge Research Center using two high range instruments. As the results obtained on this trip differed between 3 and 7 mgals from those originally determined, nearly all of the results for the first trip have been rejected. The values obtained for both sets of observations are listed in Table III along with comparative data secured by other groups.

South American Program

Although a series of gravity observations was established in South America in 1949, it was judged desirable to repeat parts of this work in view of subsequent improvement in instrumentation and change in the calibration standard used. In addition, there were large areas particularly in Brazil where there were few gravity observations. As a preliminary to the 1952 program, quick turn-about measurements were made from Washington, D.C. via Mobile, Alabama, to Panama and to Rio de Janeiro, Brazil for control purposes, and in addition, a series of "leap-frog" measurements were made between Balboa, Panama; Lima, Peru; Asuncion, Paraguay; Santiago, Chile; Buenos Aires, Argentina; and Rio de Janeiro, Brazil. With these points serving as control bases, more detailed series of measurements were carried out, particularly in Colombia, Peru, Argentina and Brazil. As most of the primary bases established in 1949 were reoccupied, it was possible to re-evaluate all of the earlier work and put it on the same calibration basis as is now being used. The adjusted values for the 1949 observations are given in the Appendix of this report along with the new values obtained. Fig. 6 shows the distribution of the principal gravity bases established in South America to date under this program.

European Measurements

In 1953, a repeat set of gravity measurements were made connecting North America and Europe via Newfoundland and the Azores. New stations were established at Shannon, Dublin, and Belfast, Ireland; Oslo, Norway; Gothenborg, Sweden; and Brussels, Belgium.

Table III
Gravity Values
Arctic Region

Canada

Ellesmere Island

Alert

1. Canadian Weather Station, southwest end of runway.
1952 CRC, USAF North American 113a 983.1367a
2. At garage, 2 feet east of west entrance.
1952 Black Worden Meter 14b 983.1410*
1952 Dominion Obs. Worden Meter 44 983.1305
1954 Rose Worden Meter 10f 983.1329
1954 Rose Worden Meter 147 983.1332

Manitoba

Churchill

RCAF Airport, to right of door leading to outside
in passenger waiting room.

- | | | | |
|------|---------------|------------------|-----------|
| 1952 | Black | Worden Meter 14b | 981.7710* |
| 1952 | Dominion Obs. | Worden Meter 44 | 981.7668 |
| 1954 | Rose | Worden Meter 10f | 981.7672 |
| 1954 | Rose | Worden Meter 147 | 981.7671 |

Northwest Territory

Isachsen

Airport, 100 yards west of unloading ramp at edge
of shore. Robert's Station.

- | | | | |
|------|---------------|------------------|-----------|
| 1952 | Black | Worden Meter 14b | 983.0665* |
| 1952 | Dominion Obs. | Worden Meter 44 | 983.0574 |
| 1954 | Rose | Worden Meter 10f | 983.0599 |
| 1954 | Rose | Worden Meter 147 | 983.0599 |

Mould Bay

Airport, at northwest corner of instrument shelter,
west side of operations shack.

- | | | | |
|------|-------|------------------|-----------|
| 1952 | Black | Worden Meter 14b | 982.9421* |
| 1954 | Rose | Worden Meter 10f | 982.9338 |
| 1954 | Rose | Worden Meter 147 | 982.9339 |

* Rejected.

Table III

Canada

Northwest Territory (con't)

Resolute

1. RCAF Airport, transit building, north of mess hall.

1952	Black	Worden Meter 14b	982.8697*
1954	Rose	Worden Meter 10f	982.8625
1954	Rose	Worden Meter 147	982.8624
2. RCAF Airport, at garage at door leading to west.

1952	Black	Worden Meter 14b	982.8701*
1954	Rose	Worden Meter 10f	982.8630
1954	Rose	Worden Meter 147	982.8630
3. RCAF Airport, 3 feet west and 2 feet south of warehouse north door on south side of runway.

1952	Black	Worden Meter 14b	982.8695*
1952	Dominion Obs.	Worden Meter 44	982.8635
4. Pendulum Base.

1952	Black	Worden Meter 14b	982.8812*
1952	Dominion Obs.	Worden Meter 44	982.8754

Ontario

Ottawa

- Dominion Observatory, top of pendulum pier.
- | | | | |
|------|--------------|------------------|----------|
| 1952 | Dominion Obs | Worden Meter 44 | 980.622 |
| 1954 | Rose | Worden Meter 10f | 980.6208 |
| 1954 | Rose | Worden Meter 147 | 980.6209 |

Toronto

Airport, at field entrance to Canadian Immigration Bureau.

- | | | | |
|------|-------|------------------|----------|
| 1952 | Black | Worden Meter 14b | 980.4304 |
| 1954 | Rose | Worden Meter 10f | 980.4301 |
| 1954 | Rose | Worden Meter 147 | 980.4303 |

Quebec

Montreal

1. Dorval Domestic Terminal, Incoming Customs Office behind long counter in building annex.

1952	Black	Worden Meter 14b	980.6442
1954	Rose	Worden Meter 10f	980.6434
1954	Rose	Worden Meter 147	980.6436
2. Dorval Inn, at west entrance on sidewalk to left of canopy.

1952	Black	Worden Meter 14b	980.6442
1954	Rose	Worden Meter 10f	980.6441
1954	Rose	Worden Meter 147	980.6443

* Rejected

Table III

Canada

Quebec

Montreal (con't)

3.	RCAF Air Movement, at northeast corner of Hangar #6.		
1952	Black	Worden Meter 14b	980.6441
1952	Dominion Obs.	Worden Meter 44	980.6455
1954	Rose	Worden Meter 10f	980.6443
1954	Rose	Worden Meter 147	980.6444

Greenland

Eureka

At instrument shed of resistance thermometer on lake.

1952	Black	Worden Meter 14b	983.0334*
1952	Dominion Obs.	Worden Meter 44	983.0251
1954	Rose	Worden Meter 10f	983.0275
1954	Rose	Worden Meter 147	983.0275

Thule

1. Airport, 125 feet south of center door of operations.

1952	CRC, USAF	North American 113a	982.9236
1952	Dominion Obs.	Worden Meter 44	982.9267
1954	Rose	Worden Meter 10f	982.9280
1954	Rose	Worden Meter 147	982.9280

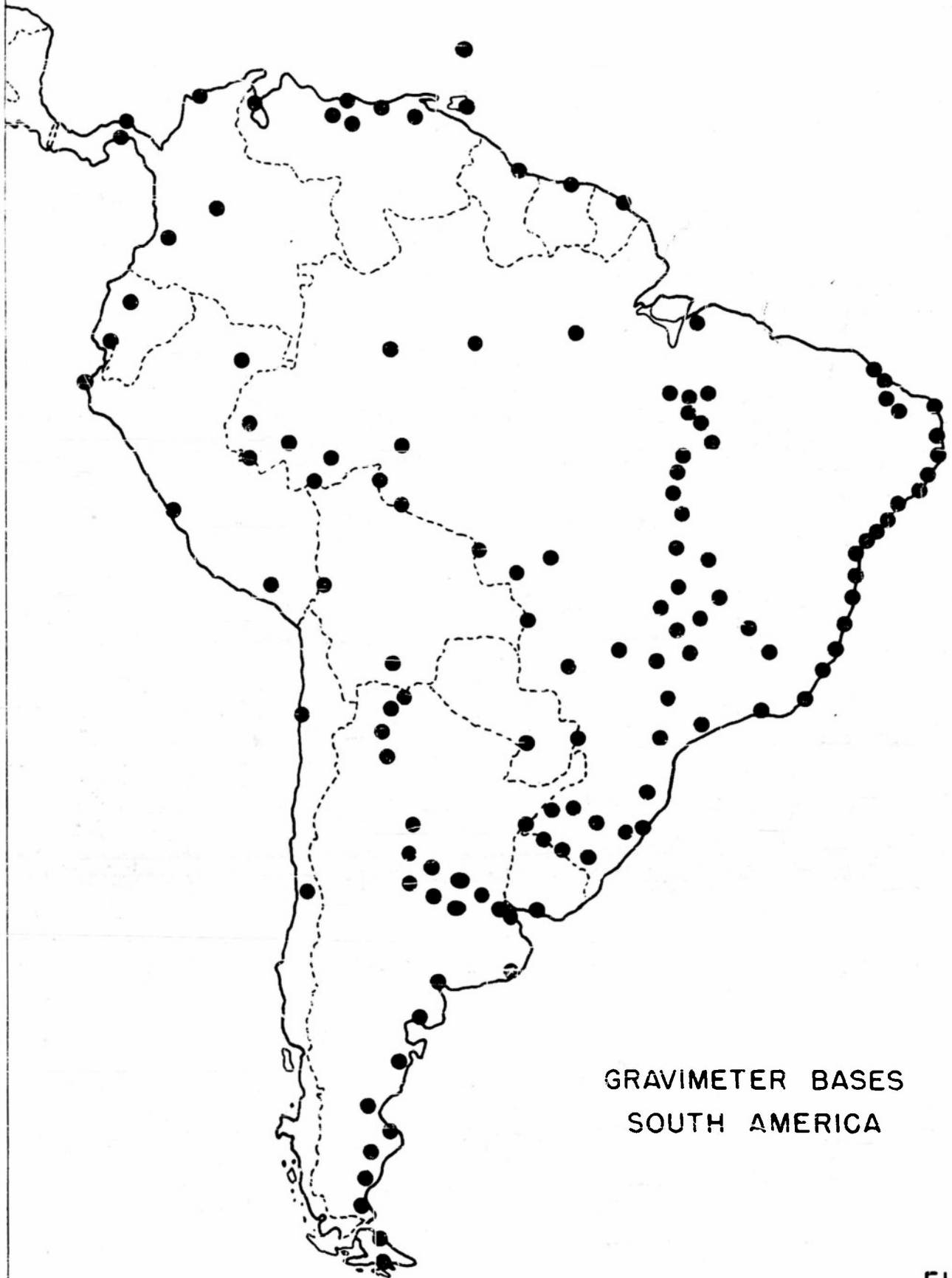
2. Danish Magnetic Station, 170 yards and 150 degrees true north from pedestal of observatory.

1952	CRC, USAF	North American 113a	982.9290
1954	Rose	Worden Meter 10f	982.9331
1954	Rose	Worden Meter 147	982.9325

3. U.S. Weather Bureau Station, southwest corner of shack, 2 feet west of entrance.

1952	Black	Worden Meter 14b	982.9401*
------	-------	------------------	-----------

* Rejected



GRAVIMETER BASES
SOUTH AMERICA

FIG.6

In February of 1954, repeat measurements were made between the absolute gravity bases of the Bureau of Standards in Washington, D.C. and the National Physical Laboratory at Teddington, England. These measurements were made as a check upon the calibration of the new high range Worden gravimeter W-147, belonging to the Air Force Cambridge Research Center and the rebuilt Worden gravimeter W-10f, which replaces meter W-10e that had been used since 1950 for most of the global measurements. On this trip, observations were made also in Newfoundland, the Azores, French Morocco and Italy. The results of these two sets of measurements are included in the Appendix.

North American Measurements

In the course of travel within the United States from Madison, Wisconsin to points of embarkation for foreign travel, a number of observations were also made at various places. The results for these measurements are included in the Appendix.

COMPARATIVE VALUES

Although the primary purpose of this study is to extend the network of gravity observations on a global basis so that certain geodetic studies can be undertaken that are now handicapped by a lack of data, the measurements have also served to indicate some of the major discrepancies in the international system of gravity bases. At first, it was not certain whether the errors indicated lay in the original pendulum observations or in the gravimeter work, but subsequent work by other investigators as well as repeat observations made under this program have verified most of the indicated discrepancies. Some of these errors have been the result of faulty measurements but others have resulted from inherent defects in the measuring equipment used.

Comparisons with Cambridge Pendulums

Comparisons of gravimeter results and those established with the Cambridge University pendulums have been made in various parts of the world. On the basis of the small standard deviation noted for the difference in results obtained and the fact that these pendulums were compensated for the effect of changes in the earth's magnetic field, they were adopted for establishing the calibration now being used in the gravimeter program. This calibration, however, was not based upon all the Cambridge pendulum data, but limited to the results obtained on individual series of measurements since there

was a suggestion of errors in the base connection to Cambridge on each program of observations. The groups of data used were those for Australia and New Zealand and those for Great Britain.

In Table IV, comparative values are given for the Cambridge pendulum stations occupied that had been established prior to 1952. In 1952, the method of magnetic compensation was changed with a Helmholtz coil around the pendulums substituted for the Mu metal liner in the pendulum case that previously had been used. Comparative data for the pendulum stations established since this change in method of magnetic compensation are given in Table V.

From an inspection of Table IV, it is seen that the differences in values fall into distinct numerical groups which correlate with the individual observational programs as follows:

Great Britain: pendulums 3.3 mgals < gravimeters
Australia: pendulums 5.3 mgals < gravimeters
South Africa: pendulums 4.5 mgals < gravimeters
East Africa: pendulums 7.0 mgals < gravimeters

The above are median values and in the case of the values in Great Britain, it is known from several subsequent repeat measurements that the difference is real and related to an error in the Potsdam system value for the Cambridge University pendulum base. As all of the other measurements were based on Cambridge, this much of the indicated discrepancy can be accounted for in each case. The balance is believed to be related to errors in the connection between Cambridge and the different areas involved. However, it is found that if an overall plot of the differences in Table IV is made, that an apparent discrepancy of about ± 1.1 mgals per 1000 mgals change is indicated in the gravimeter calibration. See Fig. 7. If the same data though are isolated into groups for each observational program (Fig. 8), no such effect is apparent except in the case of the South African measurements which indicate a departure of ± 2.4 mgals per 1000 mgals change. The explanation for this large systematic departure in South Africa is not known, but it appears to be related to the pendulum measurements. An independent series of observations that supports the conclusion that a series of errors in the Cambridge base connection is involved, rather than an erroneous calibration of the gravimeter, are the gravity measurements made by Expeditions Polaires Francaises in Great Britain, East Africa and Australia. These will be referred to in more detail later.

Similar relations to those shown by the data of Table IV are indicated for the Cambridge pendulum measurements made in North America listed in Table V. The 1953 pendulum measurements on the basis of the gravimeter measurements appear to be about 1.6 mgals

Table IV

Gravity Values at Pendulum Stations
Occupied with Cambridge University Pendulums
Magnetically Compensated with Mu Metal Liner

Cambridge pendulums relative to Cambridge (981.2650)
Gravimeters relative to Washington (980.1190)

Europe

Great Britain and Ireland	Observed Gravity	Difference in mgals
Cambridge Pendulum House		
Pendulum	981.2650	
W.H.O.I.	981.2682	+3.2
York		
Pendulum	981.4149	
W.H.O.I.	981.4174	+2.5
New Castle		
Pendulum	981.5062	
W.H.O.I.	981.5090	+2.8
Edinburgh		
Pendulum	981.5801	
W.H.O.I.	981.5834	+3.3
Aberdeen		
Pendulum	981.6959	
W.H.O.I.	981.6993	+3.4
Greenwich		
Pendulum	981.1863	
W.H.O.I.	981.1904	+4.1
Southampton		
Pendulum	981.1260	
W.H.O.I.	981.1283	+2.3
Teddington		
Pendulum	981.1923	
W.H.O.I.	981.1961	+3.8
Dublin (Dunsink)		
Pendulum	981.3858	
W.H.O.I.	981.3897	+3.9

Table IV (con't)

South America

Argentina	Observed Gravity	Difference in mgals
Buenos Aires Pendulum	979.7044	
W.H.O.I.	979.7078	+3.4

North America

United States

Washington, D.C. (Bureau of Standards)		
Pendulum	980.0954	
W.H.O.I.	980.0996	+4.2

Australia

Melbourne		
Pendulum	979.9755	
W.H.O.I.	979.9810	+5.5
Sydney		
Pendulum	979.6819	
W.H.O.I.	979.6875	+5.6
Adelaide		
Pendulum	979.7199	
W.H.O.I.	979.7258	+5.9
Ceduna		
Pendulum	979.4488	
W.H.O.I.	979.4549	+6.1
Forrest		
Pendulum	979.3027	
W.H.O.I.	979.3084	+5.7
Kalgoorlie		
Pendulum	979.2877	
W.H.O.I.	979.2929	+5.2
Perth		
Pendulum	979.3912	
W.H.O.I.	979.3970	+5.8
Geraldton		
Pendulum	979.2676	
W.H.O.I.	979.2711	+3.5

Table IV (con't)

<u>Australia</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Carnarvon		
Pendulum	978.9395	
W.H.O.I.	978.9438	+4.3
Onslow		
Pendulum	978.7695	
W.H.O.I.	978.7769	+7.4
Port Hedland		
Pendulum	978.6424	
W.H.O.I.	978.6485	+5.9
Derby		
Pendulum	978.5159	
W.H.O.I.	978.5236	+5.7
Darwin		
Pendulum	978.3128	
W.H.O.I.	978.3181	+4.7
Daly Waters		
Pendulum	978.3857	
W.H.O.I.	978.3916	+5.9
Tennant Creek		
Pendulum	978.5245	
W.H.O.I.	978.5313	+6.8
Alice Springs		
Pendulum	978.6504	
W.H.O.I.	978.6563	+5.9
Oodnadatta		
Pendulum	979.0967	
W.H.O.I.	979.1021	+5.4
Brisbane		
Pendulum	979.1657	
W.H.O.I.	979.1714	+5.7
Townsville		
Pendulum	978.6200	
W.H.O.I.	978.6268	+6.8
Cloncurry		
Pendulum	978.6478	
W.H.O.I.	978.6540	+6.2

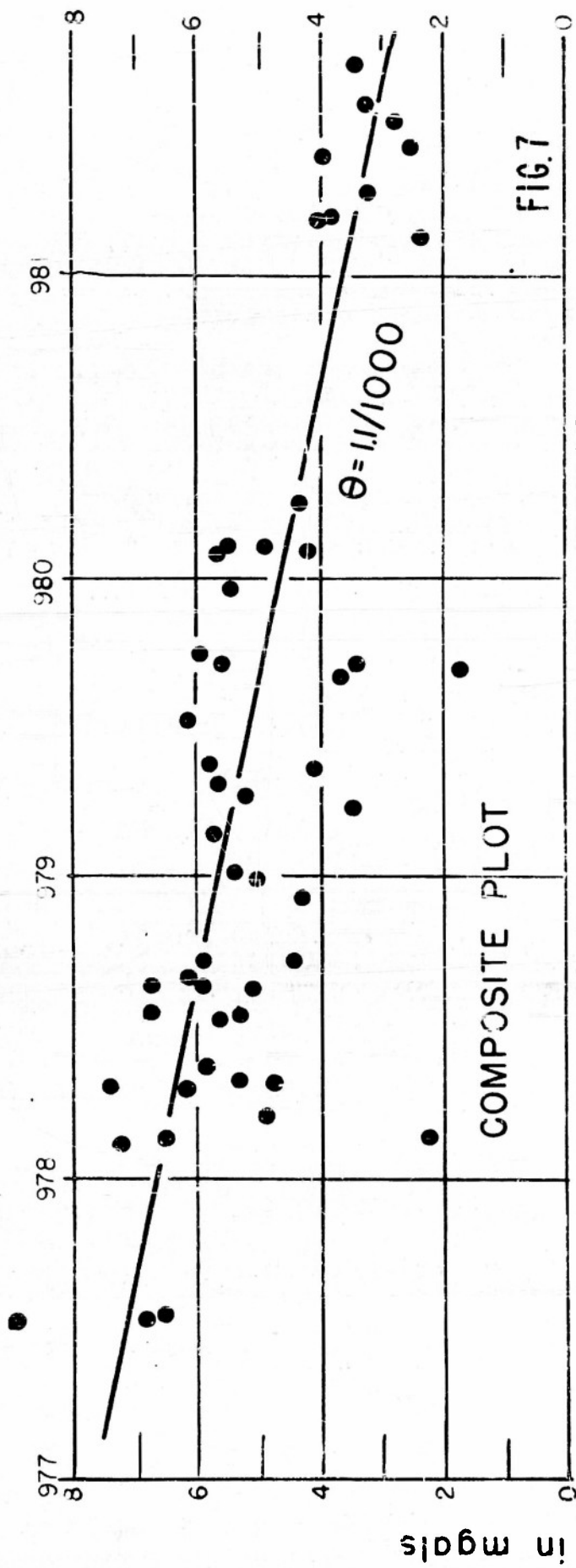
Table IV (con't)

<u>New Zealand</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Wellington		
Pendulum	980.2620	
W.H.O.I.	980.2662	+4.2
Christchurch (1)		
Pendulum	980.5046	
W.H.O.I.	980.5093	+4.7
Christchurch (2)		
Pendulum	980.5041	
W.H.O.I.	980.5096	+5.5
Otago		
Pendulum	980.7370	
W.H.O.I.	980.7426	+5.6
<u>Africa</u>		
Union of South Africa		
Capetown		
Pendulum	979.6520	
W.H.O.I.	979.6537	+1.7
Durban		
Pendulum	979.3220	
W.H.O.I.	979.3260	+4.0
Johannesburg		
Pendulum	978.5460	
W.H.O.I.	978.5514	+5.4
Mowbray		
Pendulum	979.6440	
W.H.O.I.	979.6475	+3.5
Nelspruit		
Pendulum	978.7130	
W.H.O.I.	978.7174	+4.4
Pretoria		
Pendulum	978.6260	
W.H.O.I.	978.6311	+5.1
Tsumeb		
Pendulum	978.2190	
W.H.O.I.	978.2239	+4.9

Table IV (con't)

Africa

Union of South Africa	Observed Gravity	Difference in mgals
Upington		
Pendulum	978.9880	
W.H.O.I.	978.9930	+5.0
Windhoek		
Pendulum	978.3170	
W.H.O.I.	978.3232	+6.2
Southern Rhodesia		
Salisbury		
Pendulum	978.1440	
W.H.O.I.	978.1505	+6.5
Tanganyika		
Dar es Salaam		
Pendulum	978.1176	-2.2
Pendulum	978.1126	-7.2
W.H.O.I.	978.1198	
Anglo Egyptian Sudan		
Khartoum		
Pendulum	978.3015	-4.8
Pendulum	978.2989	-7.4
W.H.O.I.	978.3063	
Kenya		
Nairobi (1)		
Pendulum	977.5237	
W.H.O.I.	977.5303	+6.6
Nairobi (2)		
Pendulum	977.5307	-6.8
Pendulum	977.5281	-9.4
W.H.O.I.	977.5375	



COMPARISON OF GRAVIMETER AND CAMBRIDGE PENDULUM VALUES

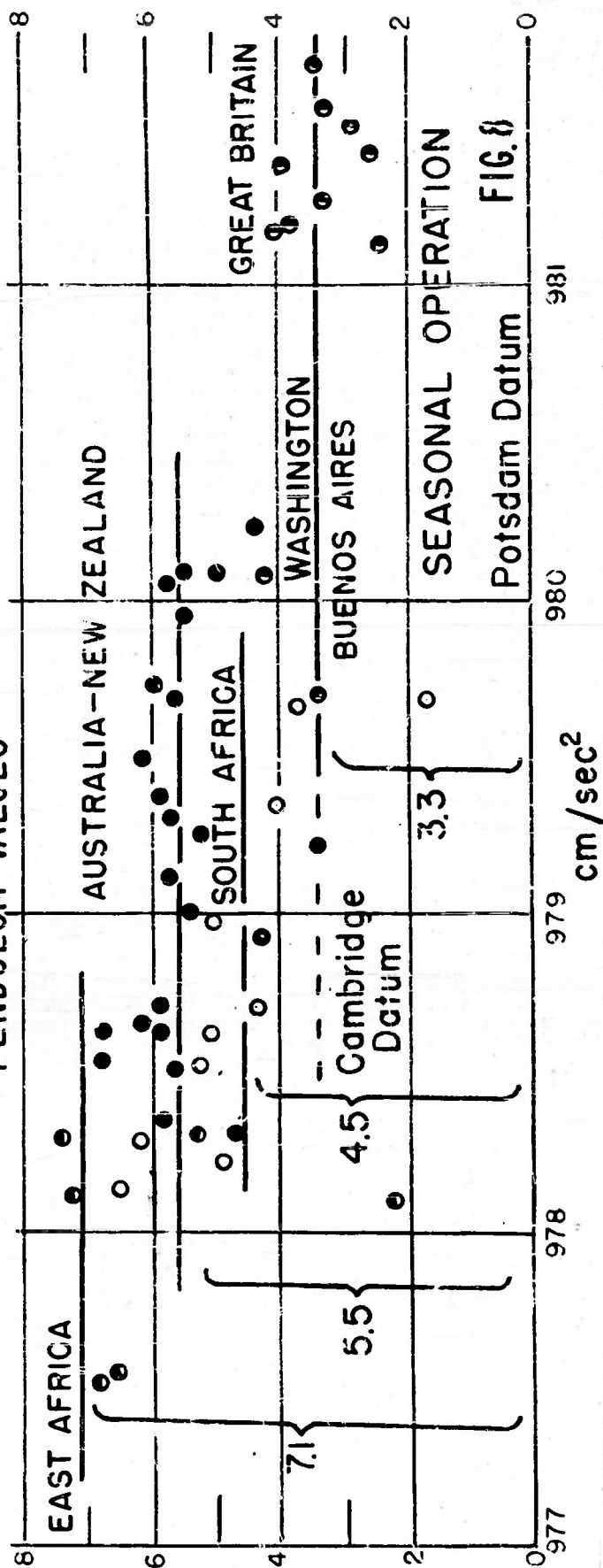


Table V

Gravity Values at Pendulum Stations
Occupied with Cambridge University Pendulums
Magnetically Compensated with a Helmholtz Coil

Cambridge Pendulum Values based on Ottawa (980.6220) Gravimeters based on Washington (980.1190)		
	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Teddington, England		
National Physical Laboratory		
Pendulum (1953)	981.1979	
W.H.O.I.	981.1961	-1.8
Washington, D.C.		
U.S. Bureau of Standards		
Pendulum (1955)	980.1013	
W.H.O.I.	980.0296	-1.7
Commerce Department		
Pendulum (1952)	980.1193	
W.H.O.I.	980.1190	-0.3
Beloit, Kansas		
Pendulum (1952)	979.9990	
W.H.O.I.	979.9986	-0.4
Houston, Texas		
Pendulum (1952)	979.2990	
W.H.O.I.	979.2988	-0.2
Tulsa, Oklahoma		
Pendulum (1952)	979.7664	
W.H.O.I.	979.7665	+0.1
Huron, South Dakota		
Pendulum (1952)	979.4555	
W.H.O.I.	979.4544	-1.1
Madison, Wisconsin		
Pendulum (1952)	980.3696	
W.H.O.I.	980.3686	-1.0
Monterrey, Mexico		
Pendulum (1952)	978.8055	
W.H.O.I.	978.8063	+0.8
Mexico City, Mexico		
Pendulum (1952)	977.9415	
W.H.O.I.	977.9440	+2.5

Table V (con't)

	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Fairbanks, Alaska		
Pendulum (1953)	982.2479	
W.H.O.I.	982.2447	-3.2
Whitehorse, Yukon Territory		
Pendulum (1953)	981.7503	
W.H.O.I.	981.7480	-2.3
Watson Lake, Yukon Territory		
Pendulum (1953)	981.7159	
W.H.O.I.	981.7132	-2.7
Fort Nelson, British Columbia		
Pendulum (1953)	981.7013	
W.H.O.I.	981.6926	-8.7
Fort St. John, British Columbia		
Pendulum (1953)	981.4074	
W.H.O.I.	981.4043	-3.1
Grand Prairie, Alberta		
Pendulum (1953)	981.3195	
W.H.O.I.	981.3168	-2.7
Edmonton, Alberta		
Pendulum (1953)	981.1686	
W.H.O.I.	981.1665	-2.1
Red Deer, Alberta		
Pendulum (1953)	981.9932	
W.H.O.I.	981.9962	-2.0
Lethbridge, Alberta		
Pendulum (1953)	980.7603	
W.H.O.I.	980.7575	-2.8

higher, on the average, than the 1952 pendulum measurements. This suggested discrepancy also appears to be substantiated by both recent gravimeter measurements and measurements made with the Gulf quartz pendulums. However, an overall difference plot indicates a discrepancy in the gravimeter calibration of ± 1.2 mgals per 1000 mgals change. This coincidence of apparent error in the present gravimeter calibration using all of the Cambridge pendulum data is so striking that repeat pendulum measurements are now being made between the United States and Canada to check its reality.

Comparisons with U.S. Coast and Geodetic Survey Pendulums

As a result of extensive series of measurements made in the United States with gravimeters over the past twenty years, it was known that there were random errors and also apparent datum shifts for different season's work in the pendulum values of the U.S. Coast and Geodetic Survey. However, it was not recognized prior to this program that the values established with the Invar pendulums of this organization were also systematically in error because of the effect of changes in the earth's magnetic field on the period of these pendulums. As shown in Fig. 9, which compares gravimeter values with pendulum values over the gravity calibration range established by the U.S. Coast and Geodetic Survey in 1950, the departure amounts to about 2.6 mgals per 1000 mgals change. Although this effect is now being eliminated in using the Invar pendulums by maintaining a constant magnetic field about the pendulums through the use of a Helmholtz coil, all observations made prior to 1952 with these pendulums incorporate an error having this origin.

That the non-systematic errors having other sources may be appreciable is indicated by the comparisons shown in Table VI, stations established with the U.S. Coast and Geodetic Survey pendulums outside the United States. It is seen that while recent work, as that in South America, appears to be in good agreement with a systematic deviation similar to that shown in Fig. 9, the older observations, particularly those in Hawaii and the Philippine Islands made with the bronze pendulums, differ markedly from the gravimeter values.

COMPARISON OF GRAVITY METER VALUES & U.S. COAST & GEODETIC SURVEY CALIBRATION VALUES

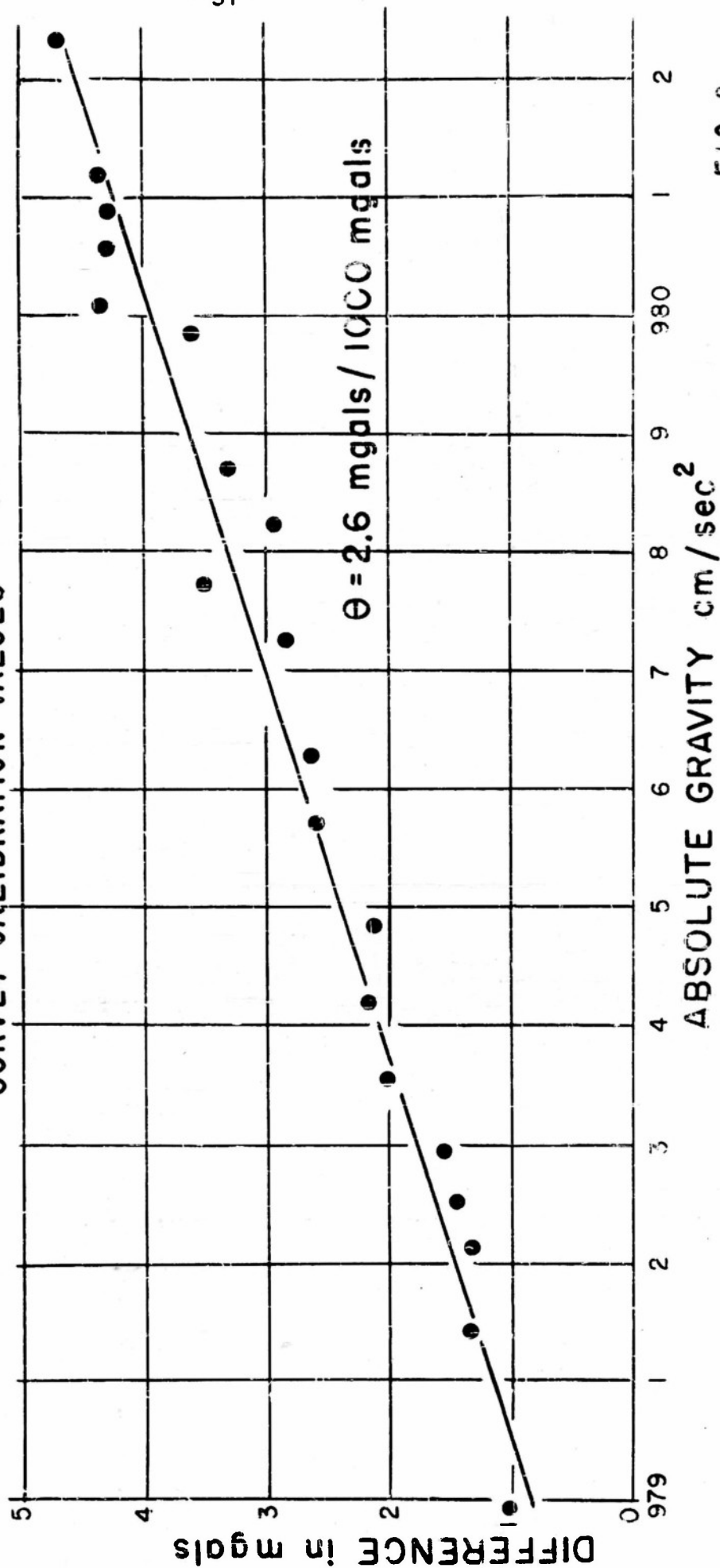


FIG. 9

Table VI

Gravity Values at Pendulum Stations
Occupied with U.S.C. & G.S. Pendulums
Outside of United States

Pendulum values based on Washington (980.1180)
Gravimeter values based on Washington (980.1190)

Part A (Invar pendulums with no magnetic compensation)

<u>South America</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Balboa, Canal Zone		
Pendulum	978.2386	
W.H.O.I.	978.2417	+3.1
Quito, Ecuador		
Pendulum	977.2790	
W.H.O.I.	977.2808	+1.8
Caracas, Venezuela		
Pendulum	978.0664	
W.H.O.I.	978.0687	+2.3
Santiago, Chile		
Pendulum	979.4293	
W.H.O.I.	979.4314	+2.1
Rio de Janeiro, Brazil		
Pendulum	978.8048	
W.H.O.I.	978.8060	+1.2

Part B (Bronze pendulums except where starred (*))

Hawaii

Honolulu		
Pendulum	978.9510	
W.H.O.I.	978.9460	-5.0
Niu Longitude Station		
Pendulum	978.9480	-8.0
Pendulum	978.9550*	-1.0
W.H.O.I.	978.9560	
Waianae (15)		
Pendulum	979.0340*	
W.H.O.I.	979.0330	-1.0
Waianae (16)		
Pendulum	979.0330*	
W.H.O.I.	979.0320	-1.0

Table VI (con't)

Part B	Observed Gravity	Difference in mgals
<u>Puerto Rico</u>		
San Juan		
Pendulum	978.6760	
W.H.O.I.	978.6776	+1.6
Mayaguez		
Pendulum	978.6690	
W.H.O.I.	978.6655	-3.5
<u>Philippine Islands</u>		
Manilla Observatory		
Pendulum	978.3720	
W.H.O.I.	978.3649	-7.1
Geodetic Survey Office		
Pendulum	978.3670	
W.H.O.I.	978.3633	-3.7
Fort McKinley		
Pendulum	978.4050	
W.H.O.I.	978.4009	-4.1

Comparisons with Vening-Meinesz Pendulums

During the course of the global program of gravimeter measurements, many of the submarine port gravity stations established using Vening-Meinesz pendulums were reoccupied. These include stations established by Vening-Meinesz personally and those made subsequently by the Lamont Geological Observatory and Cambridge University. Although pendulum values are not available as yet for most of the recent observations, the gravimeter values at all stations are listed in Table VII. The comparisons, as shown in Fig. 10, indicate a mean random error of ± 4 mgals in the pendulum values with occasional departures exceeding 10 mgals. This lack of agreement, however, is not surprising since a port location is particularly poor in that the submarine is surfaced, subject to the swell created by passing vessels and is continually bumping or rubbing against the dock.

Table VII

Gravity Values at Submarine Gravity Port Stations

Vening Meinesz Values Relative DeBilt (980.2680)

W.H.O.I. Values Relative Washington (980.1190)

<u>Africa</u>		<u>Observed Gravity</u>	<u>Difference in mgals</u>
Alexandria, Egypt			
1923	Vening-Meinesz	979.426	-5.7
1925	Vening-Meinesz	979.430	+2.3
	W.H.O.I.	979.4337	
Capetown, Union of South Africa			
1935	Vening-Meinesz	979.664	
	W.H.O.I.	979.6537	-10.3
Mowbray Observatory			
1935	Vening-Meinesz	979.656	
	W.H.O.I.	979.6435	-12.5
Dakar, French West Africa			
1934	Vening-Meinesz	978.484	
Mole #1	W.H.O.I.	978.4853	+1.3
Mole #2	W.H.O.I.	978.4847	+0.7
Mole #3	W.H.O.I.	978.4842	+0.2
Suez, Egypt			
1923	Vening-Meinesz	979.334	
	W.H.O.I.	979.3078	-26.2
Tunis, Tunisia			
1923	Vening-Meinesz	979.928	+12.8
1925	Vening-Meinesz	979.925	+ 9.8
	W.H.O.I.	979.9152	
<u>Asiatic Area</u>			
Aden			
1923	Vening-Meinesz	978.323	
	W.H.O.I.	978.3256	+2.6
Colombo, Ceylon			
1923	Vening-Meinesz	978.147	+5.1
1929	Vening-Meinesz	978.146	+4.1
	W.H.O.I.	978.1419	

Table VII

<u>Asiatic Area (con't)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Manila, Republic of the Philippines		
1926 Vening-Meinesz	978.362	
Pier #9 W.H.O.I.	978.3591	-2.9
Pier #11 W.H.O.I.	978.3603	-1.7
Singapore		
1929 Vening-Meinesz	978.087	
W.H.O.I.	978.0835	-3.5
Yokosuka, Japan		
Opama Naval Station W.H.O.I.	979.7737	
Naval Base Dock #5 W.H.O.I.	979.7805	
<u>Australia</u>		
Brisbane, Queensland		
Dalgety's Wharf W.H.O.I.	979.1724	
Eagle Street Wharf W.H.O.I.	979.1714	
Perth, West Australia		
1935 Vening-Meinesz	979.393	
W.H.O.I.	979.3958	+2.8
<u>Central America and West Indies</u>		
Balboa, Canal Zone		
Pier C W.H.O.I.	978.2405	
Pier 15C W.H.O.I.	978.2412	
Pier 18 W.H.O.I.	978.2415	
Colon (Coco Solo), Canal Zone		
1937 Vening-Meinesz	978.253	
W.H.O.I.	978.2590	+6.0
W.H.O.I.	978.2586	+5.6
W.H.O.I.	978.2583	+5.3
W.H.O.I.	978.2596	+6.6
Guantanamo Bay, Cuba		
Pier Baker W.H.O.I.	978.7506	

Table VII
Central America and West Indies

		Observed Gravity	Difference in mgals
Hamilton, Bermuda			
1937	Vening-Meinesz	979.852	
	W.H.O.I.	979.8544	+2.4
Mazatlan, Mexico			
1926	Vening-Meinesz	978.868	+5.8
1926	Vening-Meinesz	978.865	+2.8
	W.H.O.I.	978.8622	

Europe

DeBilt, Holland			
	Vening-Meinesz	980.2680	
	W.H.O.I.	980.2681	+0.1
Malta			
Dock #3			
	Cooper*	979.883	
	W.H.O.I.	979.8871	+4.1
	* based on Cambridge 981.2650 Base corr. +3.3 mgals		
Manuel Island			
	W.H.O.I.	979.8863	

North America

San Diego, California			
Naval Air Station, North Island			
	W.H.O.I.	979.5338	
Sonar School			
Reserve Pier			
	W.H.O.I.	979.5413	
School Pier			
	W.H.O.I.	979.5417	
Concrete Pierhead			
	W.H.O.I.	979.5422	
U.S. Naval Electronics School Docks			
	W.H.O.I.	979.5478	
Palisades, New York			
Lamont Observatory			
	W.H.O.I.	980.2591	
San Francisco, California			
Fort Mason, Pier #1			
1929	Vening-Meinesz	979.996	
	W.H.O.I.	979.9980	+2.0
Woods Hole, Massachusetts			
Oceanographic Inst. pumphouse			
	W.H.O.I.	980.3262	

Table VII

Pacific Area

		Observed Gravity	Difference in mgals
Guam			
	1926 Vening-Meinesz A	978.542	
	1926 Vening-Meinesz B	978.536	
Hoover Park			Relative A
	W.H.O.I.	978.5410	-0.8
Base 18			
	W.H.O.I.	978.5417	-0.3
Naval Operations Base			
	W.H.O.I.	978.5417	-0.3
Hawaiian Islands			
Honolulu			
	1926 Vening-Meinesz	978.943	
	W.H.O.I.	978.9440	+1.0
Pearl Harbor			
Sail #2			
	W.H.O.I.	978.9401	
	W.H.O.I.	978.9405	
Sail #6			
	W.H.O.I.	978.9408	
Sail #11			
	W.H.O.I.	978.9415	
Midway, Sand Island			
Berth #5			
	W.H.O.I.	978.5051	
Wake Island			
Airport			
	W.H.O.I.	978.8826	

South America

Buenos Aires, Argentina			
IGM			
	Vening-Meinesz	979.704	
IGM Potsdam Station			
	W.H.O.I.	979.7046	+0.6
IGM Absolute Station			
	W.H.O.I.	979.7065	
Meteorological Service			
	Vening-Meinesz	979.706	
	W.H.O.I.	979.7078	+1.8
	W.H.O.I.	979.7077	+1.7

Table VII

South America (con't)

Eva Peron (La Plata)

Observatory

Vening-Meinesz	979.780	
W.H.O.I.	979.7536	-26.4

Mar del Plata

IGM

Vening-Meinesz	980.036	
W.H.O.I.	980.0353	-0.7

Comparisons with Holweck-Lejay Pendulums

Although only a limited number of Holweck-Lejay pendulum bases were reoccupied, it was possible to evaluate the relative accuracy of the extensive network of gravity bases established in the Orient by LEJAY (1936). As indicated in Table VIII, the pendulum values appear to be on the average about 3 mgals below the Potsdam datum as indicated by the gravimeter values with an average deviation of about ± 2 mgals. These indications also appear to be substantiated by the measurements made in the Orient by Expeditions Polaires Francaises (STAHL, 1954). Considering the period and handicaps under which this work was done, these results are very good and the equal or better than other contemporary gravity done under more ideal circumstances.

Comparisons with Gravimeter Values, Expeditions Polaires Francaises

The global program of gravimeter measurements being carried out with constant temperature, driftless, high range North American and Western gravimeters by the Expeditions Polaires Francaises constitute the best overall check on the Woods Hole gravimeter program. Both programs have been operating independently for about the same length of time, and although there has been no marked duplication of work, it has been the policy of each group to occupy common stations at every opportunity. As a consequence, comparative data in sufficient number are available to permit the results obtained by each to be evaluated in terms of the other.

The most significant point brought out by the comparisons is that despite the fact that entirely different types of instruments are used with markedly different characteristics regarding drift and sensitivity to temperature and pressure aberrations, the results

COMPARISON OF GRAVITY METER VALUES AND VENING-MEINESZ PENDULUM VALUES

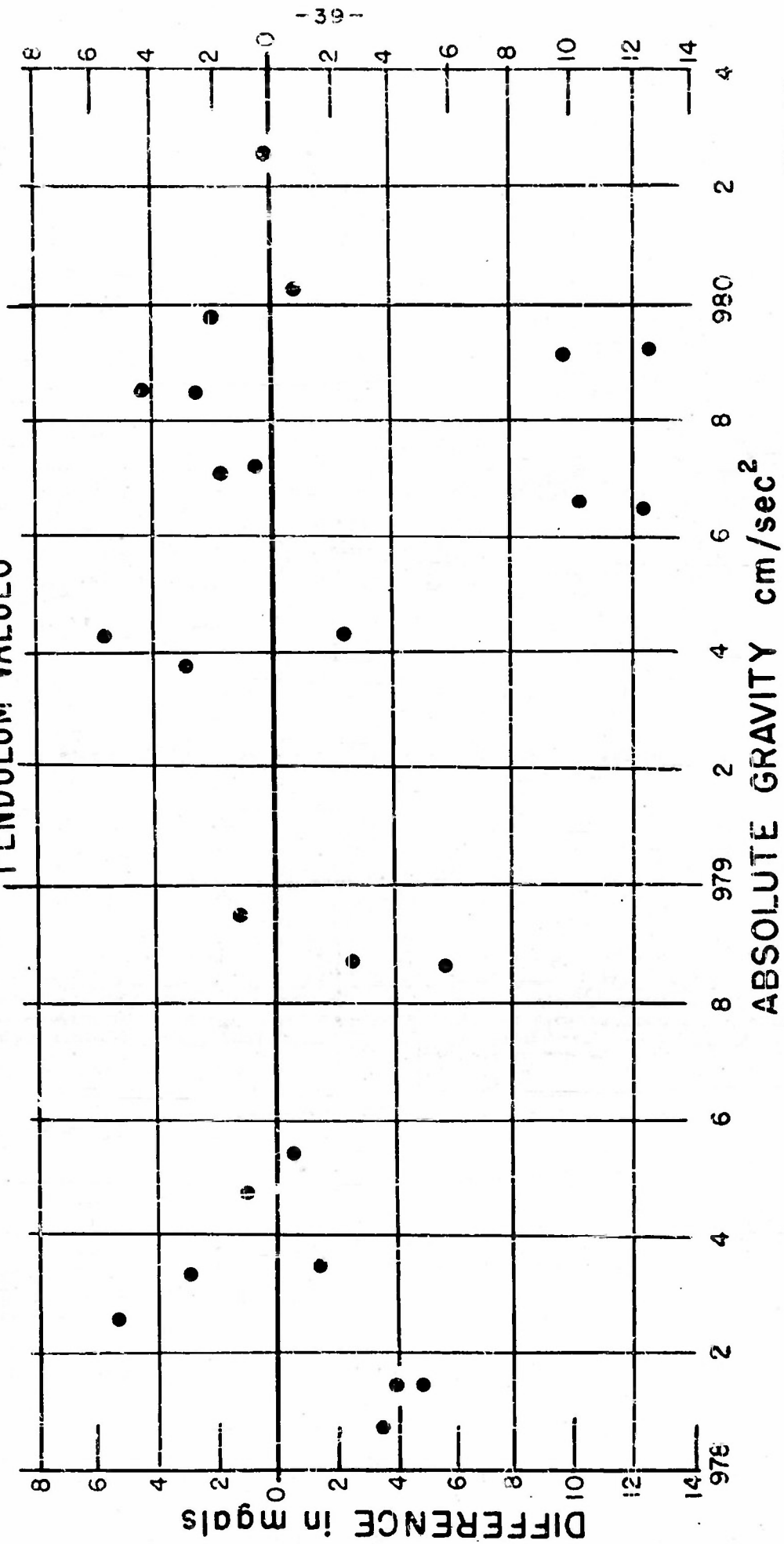


Table VIII

Gravity Values at Holweck - Lejay Pendulum Stations

Holweck-Lejay pendulums relative Paris (Radium Inst.) 980.9415
Gravimeter values relative Washington 980.1190

	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Beyrouth, Lebanon		
Lejay	979.690	-1.2
W.H.O.I.	979.6912*	
* Indirect tie by Exp. Pol. Fran.		
Hong Kong		
Lejay	978.767	-4.1
W.H.O.I.	978.7721	
Colombo, Ceylon		
Lejay	978.135	+0.5
W.H.O.I.	978.1345	
Saigon, Indo China		
Lejay	978.228	-2.7
W.H.O.I.	978.2307	
Manila, Republic of the Philippines		
Lejay	978.3590	-6.0
W.H.O.I.	978.3650	
Singapore		
Lejay	978.085	+1.5
Lejay	978.082	-1.5
W.H.O.I.	978.0835	

The following values are extrapolated allowing for change in position, elevation and anomaly gradient.

Hanoi, Indo China		
Lejay	978.682	-6.0
W.H.O.I.	978.683	
Hue, Indo China		
Lejay	978.442	-4.0
W.H.O.I.	978.446	
Shanghai, China		
Lejay	979.436	-3.0
W.H.O.I.	979.439	

agree, on the whole, very well; the principal sources of difference being related to a systematic deviation because of the difference in calibration standard used by each group, and tares (jumps) in readings caused by jarring the instruments in transit. The Woods Hole measurements, as explained earlier, are based upon a calibration using the Cambridge pendulum values as a standard. The French measurements are based upon a calibration derived from the gravity interval between the Paris and Toulouse Observatories, as determined with gravimeters in terms calibrated against various national gravity bases in Europe. This difference in calibration results in a deviation of about -1.1 mgals per 1000 mgals change in the Woods Hole results. The significance of jars to the instrument suffered in transit can only be evaluated through repeat measurements or comparisons with other measurements. On the basis of present comparisons, these seldom have amounted to as much as a mgal. The comparisons with the results obtained by Expeditions Polaires Francaises to date are tabulated in Table IX.

If the differences shown in Table IX are plotted as shown in Fig. 11, there appears to be a random difference between the two sets of values having a mean value of ± 0.9 mgals, and no indication of any systematic deviation due to difference in calibration standard. However, if work done during individual field seasons with a single instrument are considered, the systematic departures and tares referred to become apparent and the standard deviation is reduced from 0.6 mgals to 0.3 mgals. This is shown graphically in Fig. 12.

The difference in slopes of the error (difference) curves for the work of MARTIN and that of STAHL suggests a difference in calibration of the instruments used. However, whether the error lies with the Worden gravimeters or the North American gravimeters cannot be said at this time. It should be possible to resolve this, though, after the completion of this summer's work, in which two Worden gravimeters are being used to occupy key points in all the continental networks established to date.

Closing Statement

From the comparative data included in this report, it is obvious that a major limiting factor in the use of gravimeters for geodetic measurements is the calibration of the instrument. At this writing, there is no internationally accepted gravity standard that can be used for calibration purposes. The cooperative program of the Dominion Observatory of Canada, the U.S. Coast and Geodetic Survey and the Woods Hole Oceanographic Institution to establish a suitable calibration range with pendulums between Mexico and Alaska is still not complete. As indicated in Table V, the gravimeter data suggests there is a "tare" (jump) between the two field

Table IX

Comparisons on World Basis with
Expeditions Polaires Francaises (EPF)

North American and Western gravimeters based on Paris (980.9430)
Worden gravimeters based on Washington (980.1190)

	<u>Observed Gravity</u>	<u>Difference in mgals</u>
<u>Africa</u>		
Algiers		
Algiers Airport		
E.P.F.	979.9076	
W.H.O.I.	979.9055	-2.1
Belgium Congo		
Leopoldville Airport		
E.P.F.	977.9555	
W.H.O.I.	977.9548	-0.7
French Morocco		
Ber Rechid (1)		
E.P.F.	979.5573	
W.H.O.I.	979.5558	-1.5
Ber Rechid (2)		
E.P.F.	979.5593	
W.H.O.I.	979.5577	-1.6
Casablanca		
E.P.F.	979.6441	
W.H.O.I.	979.6425	-1.6
Port Lyautey		
E.P.F.	979.6533	
W.H.O.I.	979.6521	-1.2
French West Africa		
Dakar Airport		
E.P.F.	978.4793	
W.H.O.I.	978.4801	+0.8
Gold Coast		
Accra Airport		
E.P.F.	978.1188	
W.H.O.I.	978.1178	-1.0
Kenya		
Mombasa Airport		
E.P.F.	978.0528	
W.H.O.I.	978.0520	-0.8

Table IX (con't)

<u>Africa (con't)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Kenya		
Nairobi		
Eastleigh		
E.P.F.	977.5476	
W.H.O.I.	977.5456	-2.0
Bullard I		
E.P.F.	977.5326	
W.H.O.I.	977.5303	-2.3
Bullard II		
E.P.F.	977.5390	
W.H.O.I.	977.5375	-1.5
West Airport		
E.P.F.	977.5387	
W.H.O.I.	977.5365	-2.2
Madagascar		
Tananarive Airport		
E.P.F.	978.2204	
W.H.O.I.	978.2198	-0.6
Tananarive Observatory		
E.P.F.	978.2264	
W.H.O.I.	978.2258	-0.6
Tananarive IRSM		
E.P.F.	978.2481	
W.H.O.I.	978.2476	-0.5
Northern Rhodesia		
Abercorn		
E.P.F.	977.6753	
W.H.O.I.	977.6739	-1.4
Kasama Airport		
E.P.F.	977.7921	
W.H.O.I.	977.7909	-1.2
N'Dola Airport		
E.P.F.	977.9167	
W.H.O.I.	977.9155	-1.2
Sierra Leone		
Freetown Airport		
E.P.F.	978.2018	
W.H.O.I.	978.2027	+0.9

Table IX (con't)

<u>Africa (con't)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Tanganyika		
Dar es Salaam Airport		
E.P.F.	978.1205	
W.H.O.I.	978.1195	-1.0
Bullard Station		
E.P.F.	978.1205	
W.H.O.I.	978.1198	-0.7
<u>Asia</u>		
French Indo China		
Saigon		
Airport		
E.P.F.	978.2318	
W.H.O.I.	978.2324	+0.6
Procure Mission		
E.P.F.	978.2502	
W.H.O.I.	978.2307	+0.5
India		
Calcutta Airport		
E.P.F.	978.8092	
W.H.O.I.	978.8091	-0.1
Iraq		
Basrah Airport		
E.P.F.	979.3259	
W.H.O.I.	979.3247	-1.2
Lebanon		
Beirut Airport		
E.P.F.	979.6922	
W.H.O.I.	979.6912	-1.0
Pakistan		
Karachi Airport		
E.P.F.	978.6929	
W.H.O.I.(1)	978.9634	+0.5
W.H.O.I.(2)	978.9626	-0.3

Table IX (con't)

<u>Asia (con't)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Singapore		
Airport		
E.P.F.	978.0831	
W.H.O.I.	978.0843	+1.1
Mt. Elizabeth Road		
E.P.F.	978.0828	
W.H.O.I.	978.0835	+0.7
Bank Indochine		
E.P.F.	978.0818	
W.H.O.I.	978.0827	+0.9
<u>Australian Area</u>		
Australia		
Brisbane		
Globe Hotel		
E.P.F.	979.1708	
W.H.O.I.	979.1716	+0.8
Dalgety's Wharf		
E.P.F.	979.1696	
W.H.O.I.	979.1714	+1.2
Darwin		
Airport.		
E.P.F.	978.3167	
W.H.O.I.	978.3181	+1.4
Hotel		
E.P.F.	978.3138	
W.H.O.I.	978.3152	+1.4
Melbourne		
Airport		
E.P.F.	979.9627	
W.H.O.I.	979.9610	+1.3
Footscray		
E.P.F.	979.9796	
W.H.O.I.	979.9810	+1.4

Table IX (con't)

<u>Australian Area (con't)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Australia		
Sydney		
Airport		
E.P.F.	979.6992	
W.H.O.I.	979.7007	+1.5
Rose Bay		
E.P.F.	979.6964	
W.H.O.I.	979.6978	+1.4
National Bureau of Standards		
E.P.F.	979.6864	
W.H.O.I.	979.6875	+1.1
New Caledonia		
Noumea, IFO		
E.P.F.	978.8808	
W.H.O.I.	978.8824	+1.6
Tasmania		
Hobart Airport		
E.P.F.	980.4418	
W.H.O.I.	980.4439	+2.1
Launceston		
E.P.F.	980.2764	
W.H.O.I.	980.2784	+2.0
Indonesia		
Batavia Airport		
E.P.F.	978.1653	
W.H.O.I.	978.1669	+1.6
<u>Europe</u>		
Belgium		
Brussels Airport		
E.P.F.	981.1602	
W.H.O.I.	981.1613	+1.1
Denmark		
Copenhagen		
Kastrup Airport		
E.P.F.	981.5567	
W.H.O.I.	981.5572	+0.5
Buddinge Base		
E.P.F.	981.5571	
W.H.O.I.	981.5574	+0.3

Table IX (con't)

<u>Europe (con't)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
France		
Bordeaux Airport		
E.P.F.	980.5778	
W.H.O.I.	980.5780	+0.2
Paris		
Le Bourg t Airport		
E.P.F.	980.9498	
W.H.O.I.	980.9498	0.0
Orly Airport		
E.P.F.	980.9157	
W.H.O.I.	980.9157	0.0
Paris Observatory (new base)		
E.P.F.	980.9439	
W.H.O.I.	980.9439	0.0
Great Britain		
Glasgow, Scotland		
University		
E.P.F.	981.5944	
W.H.O.I.	981.5942	-0.2
Greenwich, England		
E.P.F.	981.1908	
W.H.O.I.	981.1904	-0.4
Edinburgh, Scotland		
E.P.F.	981.5832	
W.H.O.I.	981.5834	+0.2
London, England		
Heath Row Airport		
E.P.F.	981.2015	
W.H.O.I.	981.2015	0.0
Teddington, England		
NPL		
E.P.F.	981.1962	
W.H.O.I.	981.1961	-0.1

Table IX (cont)

<u>Europe (cont)</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
<u>Italy</u>		
<u>Rome</u>		
Ciampino Airport		
E.P.F.	980.3496	
W.H.O.I.	980.3483	-0.7
<u>Engineering College</u>		
E.P.F.	980.3626	
W.H.O.I.	980.3633	+0.7
<u>Netherlands</u>		
<u>Amsterdam Airport</u>		
E.P.F.	981.2877	
W.H.O.I.	981.2867	-1.0
<u>Debilt</u>		
E.P.F.	981.2687	
W.H.O.I.	981.2681	-0.6
<u>Portugal</u>		
<u>Lisbon Airport</u>		
E.P.F.	980.0798	
W.H.O.I.	980.0786	-1.2
<u>Sweden</u>		
<u>Stockholm</u>		
Bromma Airport		
E.P.F.	981.8445	
W.H.O.I.	981.8440	-0.5
<u>RAX base</u>		
E.P.F.(1)	981.8452	+0.3
E.P.F.(2)	981.8450	+0.1
W.H.O.I.	981.8449	
<u>Iceland</u>		
<u>Keflavik Airport</u>		
E.P.F.	982.2731	
W.H.O.I.	982.2716	-1.5
<u>Reykjavik</u>		
E.P.F.	982.2800	
W.H.O.I.	982.2781	-1.9

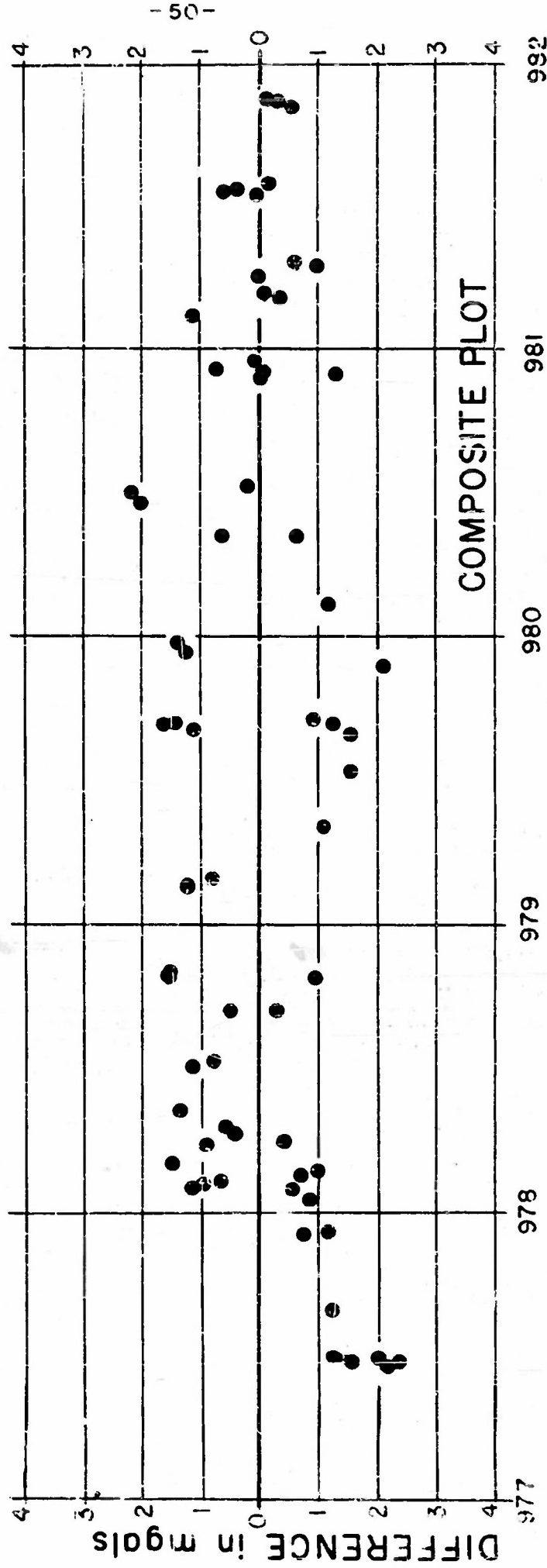
Table IX (con't)

<u>Newfoundland</u>	<u>Observed Gravity</u>	<u>Difference in mgals</u>
Gander Airport		
E.P.F.	980.9590	
W.H.O.I. (Worden)	980.9576	-1.4
W.H.O.I. (Frost)	980.9598	+0.8

season's work with the Cambridge pendulums. The original measurements made with Gulf pendulums in 1951 have been rejected as not having sufficient accuracy for calibration purposes. The second series of Gulf pendulum measurements made in 1953, while in substantial agreement with the Cambridge pendulum values, also suggests a "tare" between the 1952 and 1953 Dominion Observatory measurements. The U.S. Coast and Geodetic Survey values, while in good agreement by usual standards of comparison with the other pendulum values, are not extensive enough to resolve the suggested discrepancy. In order to settle this uncertainty which is critical, relative measurements are being made with the Gulf pendulums between Canada and the United States connecting observation points occupied with the Cambridge pendulums in 1952 and 1953. Unfortunately, the results of these measurements will not be available in time for the meetings of the International Association of Geodesy in September as it had been hoped that an international gravity standard could be adopted this year.

The other problem in connection with gravimeter work, namely jumps in values, is similar to the base connection errors in pendulum work, and the only solution appears to be frequent closures. For this reason, the program of gravimeter measurements being made this summer involves a series of "leap-frog" connections between the various bases as set forth in Table X.

COMPARATIVE GRAVIMETER VALUES EXPEDITIONS POLAIRES FRANCAISES VS WOODS HOLE OCEANOGRAPHIC INSTITUTION



COMPARISON OF WOODS HOLE & EXPEDITIONS POLAIRES FRANCAISES GRAVITY VALUES

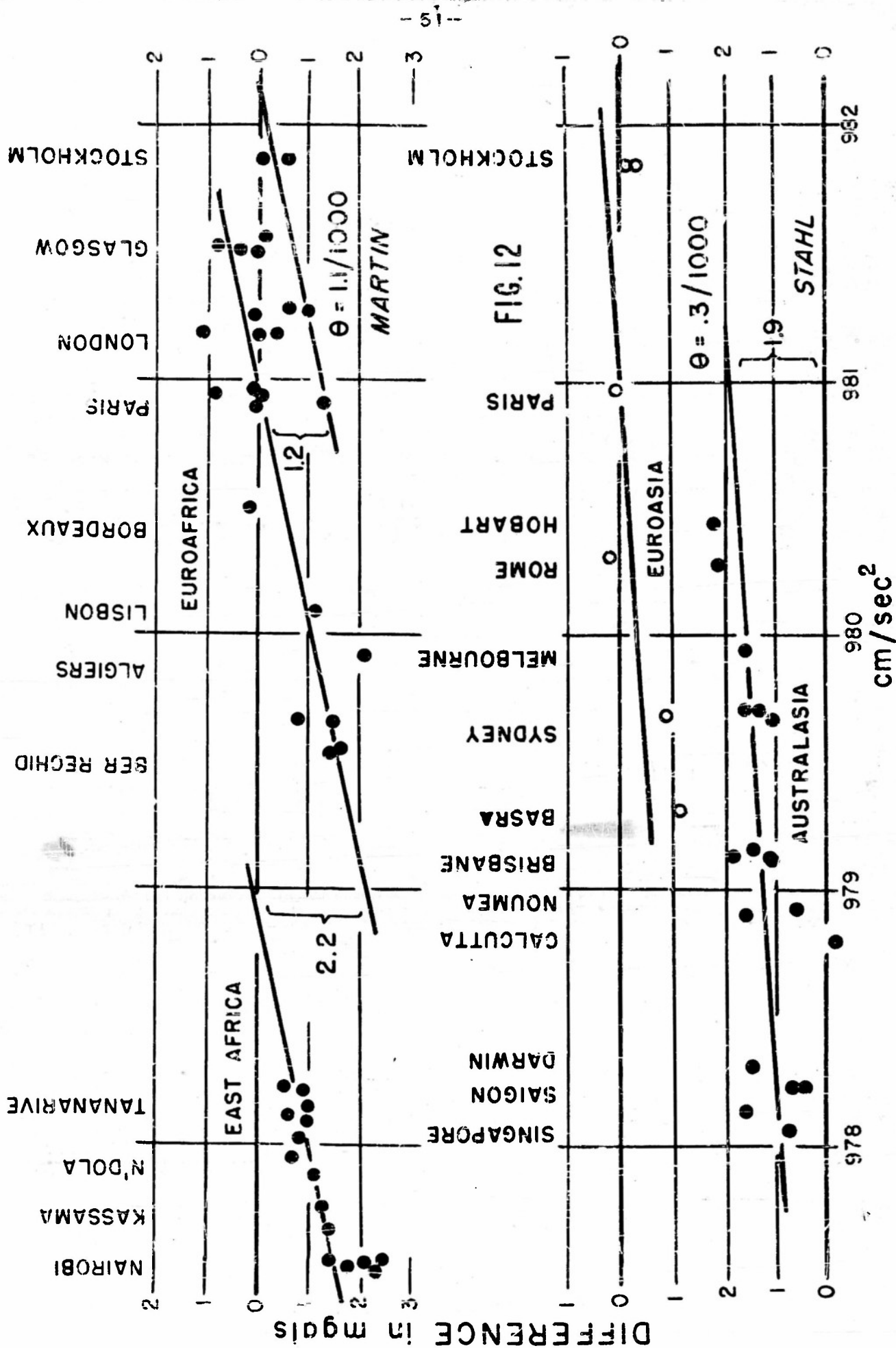


Table X

Itinerary, 1954 Gravimeter Program

Washington - Pt. Lyautey - Tripoli

Tripoli - Athens - Rome - Athens - Tripoli - Rome

Rome - Madrid - Lisbon - Madrid - Rome

Rome - Tripoli - Kano - Leopoldville - Johannesburg - Capetown -
Johannesburg

Johannesburg - Nairobi - Khartoum - Cairo - Tripoli

Tripoli - Athens - Ankara - Athens - Rome

Rome - Zurich - Belgrade - Zurich - Rome

Rome - Naples - London - Naples - Rome

Rome - Naples - London - Paris - Bad Harzburg - London

London - Copenhagen - Oslo - Copenhagen - London

London - Naples - Rome

Rome - Tripoli - Dhahran - Nicosia - Beyrouth - Nicosia - Tripoli -
Dhahran

Dhahran - Karachi - Dehli - Calcutta - Bangkok - Saigon - Clark
(Manila)

Manila - N. Borneo - Singapore - Darwin - Melbourne - Darwin -
Singapore - Manila - Clark - Manila - Clark

Clark - Tokyo

Tokyo - Clark - Saigon - Bangkok - Calcutta - Dehli - Karachi -
Dhahran - Tokyo

Tokyo - Hawaii - Tokyo - Hawaii - San Francisco - Hawaii - San
Francisco

San Francisco - Washington - San Francisco - Washington

Washington - Westover - Thule - Westover - Tripoli - Westover -
Washington - Westover - Washington

Table X (con't)

Washington - Mobile - Rio de Janeiro - Mobile

Mobile - Panama - Mobile - Washington

Washington - Ottawa - Washington

ACKNOWLEDGEMENTS

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APPENDIX

Part I

ATLANTIC - EUROPEAN AREA

Azores

Belgium

British Isles

Denmark

France

French Morocco

Italy

Norway

Sweden

Azores

Terceira Island

Lagens Air Base

1. In lobby alcove leading to terrace on field side of terminal.

1948	Woollard*	Worden Meter 10b	g	980.1760
1950	Harding*	Worden Meter 41b	g	980.1759
1951	Woollard*	Worden Meter 10e	g	980.1761
1951	Bonini *	Worden Meter 10e	g	980.1764
1952	Woollard	Frost Meter	g	980.1770
1952	Bonini	Worden Meter 126	g	980.1762
1953	Woollard	Worden Meter 10e	g	980.1763
1954	Woollard	Worden Meter 10f	g	980.1760
1954	Woollard	Worden Meter 147	g	980.1760

* old site no longer available

2. Officers' Club, on top of front step, station entrance.

1951	Bonini	Worden Meter 10e	g	980.1646
1952	Woollard	Frost Meter	g	980.1653
1952	Bonini	Worden Meter 126	g	980.1645
1953	Woollard	Worden Meter 10e	g	980.1649
1954	Woollard	Worden Meter 10f	g	980.1642
1954	Woollard	Worden Meter 147	g	980.1642

3. On top of small brick wall on terminal side of Portuguese Administration Building.(new terminal)

1951	Woollard	Worden Meter 10e	g	980.1759
1951	Bonini	Worden Meter 10e	g	980.1763

Belgium

Brussels

Airport, by telegraph booth under clock in main lobby of terminal.

1953	Woollard	Worden Meter 10e	g	981.1613
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British Isles

England

Blackbushe

RAF Base, at passenger entrance to old terminal, to right rear when facing new terminal.

1952	Woollard	Frost Meter	g	981.1550
1952	Bonini	Worden Meter 126	g	981.1552
1953	Woollard	Worden Meter 10e	g	981.1552
1953	Woollard	Worden Meter 142	g	981.1551

British Isles (continued)

England

Cambridge

University of Cambridge Pendulum House on
Observatory grounds. Pendulum Base.

1948	Woollard	Worden Meter 10b	g	981.2684
1951	Woollard	Worden Meter 10e	g	981.2681
1951	Bonini	Worden Meter 10e	g	981.2679
1952	Woollard	Frost Meter	g	981.2684
1952	Bonini	Worden Meter 126	g	981.2679

London

1. Grosvenor Square, U.S. Naval Headquarters, on left side of vestibule between inner and outer doors of North Audley Street entrance.

1948	Woollard	Worden Meter 10b	g	981.2001
1951	Woollard	Worden Meter 10e	g	981.2000
1951	Bonini	Worden Meter 10e	g	981.2003
1952	Woollard	Frost Meter	g	981.2002
1952	Bonini	Worden Meter 126	g	981.2001
1953	Woollard	Worden Meter 10e	g	981.2001
1953	Woollard	Worden Meter 142	g	981.2001
1954	Woollard	Worden Meter 10f	g	981.2002
1954	Woollard	Worden Meter 147	g	981.2003
2. Hendon Airport, on ground to left of door leading from runway into lounge of terminal building.

1948	Woollard	Worden Meter 10b	h	981.2066
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3. Northolt Airport, Continental Departures Building, in customs room to right of door leading to waiting room.

1948	Woollard	Worden Meter 10b	g	981.2076
1953	Woollard	Worden Meter 10e	g	981.2081
1953	Woollard	Worden Meter 142	g	981.2080
4. Northolt Airport, at wall to right facing bar in main terminal opposite the TWA Counter.

1953	Woollard	Worden Meter 10e.	g	981.2013
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6. London Airport (Heath Row), in passenger lounge in front of PAA counter.

1954	Woollard	Worden Meter 10f	g	981.2016
1954	Woollard	Worden Meter 147	g	981.2014
7. London Airport (Heath Row), new terminal at foot of left ramp to right gangway facing terminal.

1954	Woollard	Worden Meter 10f	g	981.1995
1954	Woollard	Worden Meter 147	g	981.2000

British Isles (continued)

England

London

7. Keysign Building, corner of Balderton and Oxford Streets, Office of Naval Research Headquarters, inside lobby to left of entrance.

1952	Woollard	Frost Meter	g	981.2013
1954	Woollard	Worden Meter 10f	g	981.2009
1954	Woollard	Worden Meter 147	g	981.2009

Teddington

1. National Physical Laboratories, Meteorology Building, room #11, on concrete floor level pier.

1948	Woollard	Worden Meter 10b	g	981.1961
1951	Woollard	Worden Meter 10e	g	980.1960
1951	Bonini	Worden Meter 10e	g	981.1960
1951	Bonini	Worden Meter 10e	g	981.1961
1952	Woollard	Frost Meter	g	981.1962
1952	Bonini	Worden Meter 126	g	981.1960
1954	Woollard	Worden Meter 10f	g	981.1962
1954	Woollard	Worden Meter 147	g	981.1964

2. National Physical Laboratories, Main Gate Lodge, on north side of building next to drain.

1951	Bonini	Worden Meter 10e	g	981.1966
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Ireland

Belfast

1. 60 Locksley Road, on hearth.

1953	Woollard	Worden Meter 10e	g	981.4964
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2. On the corner of Claremont Street and University Road Lane on curb. (Murphy gravimeter station)

1953	Woollard	Worden Meter 10e	g	981.4998
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3. Nutts Corner Airport, at corner of control tower on manhole plate by road.

1953	Woollard	Worden Meter 10e	g	98.4789
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Dublin

Airport, on ramp area on side of terminal.

1953	Woollard	Worden Meter 10e	g	981.3997
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Dunsink

Pendulum Base in basement shop of the Astronomical Observatory.

1953	Woollard	Worden Meter 10e	g	981.3897
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British Isles (continued)

Ireland

Shannon

Airport, just inside terminal at transit
passenger door.

1952	Woollard	Frost Meter	g	981.3421
1952	Bonini	Worden Meter 126	g	981.3418

Denmark

Copenhagen

1. Kastrup Airport, outside at field entrance
for passengers to main terminal building.
1948 Woollard Worden Meter 10b g 981.5574
1953 Woollard Worden Meter 10e g 981.5571
1953 Woollard Worden Meter 142 g 981.5573
2. Kastrup Airport, inside terminal to left of
door facing out.
1953 Woollard Worden Meter 10e g 981.5570
3. Danish Geodetic Survey, on pier in gravity
vault. Pendulum Base. (Buddinge)
1948 Woollard Worden Meter 10b g 981.5574
4. Danish Geodetic Survey, concrete slab on road-
way outside entrance to gravity vault.
1948 Woollard Worden Meter 10b g 981.5570
5. Danish Geodetic Institute, Proviantgaarden, on
pier in the office of Dr. Andersen.
1953 Woollard Worden Meter 10e g 981.5592
1953 Woollard Worden Meter 142 g 981.5594

France

Paris

1. Orly Airport, at MATS Terminal to right of
passenger entrance from field.
1952 Woollard Frost Meter g 980.9172
1952 Bonini Worden Meter 126 g 980.9157
2. Orly Airport, in Officers' Club on hearth of
fireplace.
1952 Woollard Frost Meter g 980.9175
1952 Bonini Worden Meter 126 g 980.9162

French Morocco

Port Lyautey

Naval Air Station

1. On walk alongside terminal building between entrance to V-24 Operations office and waiting room. (old terminal)

1948	Woollard	Worden Meter 10b	g	979.6531
1950	Harding	Worden Meter 41b	g	979.6519
1951	Bonini	Worden Meter 10e	g	979.6525
1952	Woollard	Frost Meter	g	979.6505
1952	Bonini	Worden Meter 126	g	979.6525
1954	Woollard	Worden Meter 10f	g	979.6517
1954	Woollard	Worden Meter 147	g	979.6517
2. Officers Club, in front of reception desk.

1950	Harding	Worden Meter 41b	g	979.6442
1951	Bonini	Worden Meter 10e	g	979.6449
1954	Woollard	Worden Meter 10f	g	979.6441
1954	Woollard	Worden Meter 147	g	979.6442
3. New terminal, on covered front porch facing field, next to glass wall at center pane.

1954	Woollard	Worden Meter 10d	g	979.6518
1954	Woollard	Worden Meter 147	g	979.6517

Italy

Naples

Capodichino Airport

1. In terminal building in front of the telegraph office. (civilian terminal)

1951	Bonini	Worden Meter 10e	g	980.2565
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2. At MATS Terminal, inside door from field.

1952	Woollard	Frost Meter	g	980.2575
1952	Bonini	Worden Meter 126	g	980.2572
1954	Woollard	Worden Meter 10f	g	980.2568
1954	Woollard	Worden Meter 147	g	980.2564

Norway

Oslo

1. Fornebu Airport, in terminal at cashier's desk opposite weighing-in counter.

1953	Woollard	Worden Meter 10e	g	981.9324
1953	Woollard	Worden Meter 142	g	981.9322
2. Mineralogisk Geologisk og Paleontologisk Museum, in basement. (pendulum base)

1953	Woollard	Worden Meter 10e	g	981.9288
1953	Woollard	Worden Meter 142	g	981.9290

Sweden

Gothenburg

Airport, at right edge of flagstone court
at runway, in front of terminal.

1953	Woollard	Worden Meter 10e	g	981.7439
1953	Woollard	Worden Meter 142	g	981.7450

Part II

CENTRAL AMERICAN AREA

British West Indies

Costa Rica

Cuba

Guatemala

Honduras

Nicaragua

Panama Canal Zone

Puerto Rico

Salvador

Note: All values marked with * are revised values
on Cambridge Pendulum calibration

British West Indies

Antigua

Coolidge AFB, airport waiting room, just left
of information window.
1949 Harding Worden Meter 10c g 978.6560 *

St. Lucia

Beane Field, on cross walk along parking ramp
between crew and passenger walks to terminal.
1949 Harding Worden Meter 10c g 978.5349 *

Trinidad

Piarco Airport, in waiting room of terminal by
doorway to incoming customs and baggage room.
1949 Harding Worden Meter 10c g 978.1653 *
1951 Bonini Worden Meter 10e g 978.1636

Costa Rica

(These values supercede those in Ref. No. 52-59)

San Jose

1. Municipal Airport, at Pan American Airways
terminal at steps leading to office on field
level.
1952 Black Worden Meter 10e g 977.9485
2. Triangulation BM #17-SJ de lax Instituto Geo-
grafico de Costa Rica. Station is at SE corn-
er of control tower, on top of tower.
1952 Black Worden Meter 10e g 977.9436
3. Golf Club grounds at Instituto Geografico de
Costa Rica Magnetic station on top of concrete
pillar three inches below ground.
1952 Black Worden Meter 10e g 977.9517

Alajuela

East side of church at BM #44-C.
1952 Black Worden Meter 10e g 977.9706

Artieda

At triangulation station, on plaque.
1952 Black Worden Meter 10e g 977.6669

Asuncion

On BM #349.
1952 Black Worden Meter 10e g 977.5169

Cariblanco

BM #798A.
1952 Black Worden Meter 10e g 978.0138

Costa Rica (continued)

Ciruelas

BM #11A, 150 meters west of highway.
1952 Black Worden Meter 10e g 978.0152

Cartago

West side of plaza at BM (Vasquez BM #30C).
1952 Black Worden Meter 10e g 977.8864

Grecia

At Catholic church at east side of plaza at entrance to church on top step, and three feet west of doors leading to church.
1952 Black Worden Meter 10e g 977.9569

Esparta

Catholic church on south side of plaza at BM #211.
1952 Black Worden Meter 10e g 978.1699

Heredia

BM #1-M. Over plate at north side of plaza, 100 feet east and 75 feet south of southeast corner of post office.
1952 Black Worden Meter 10e g 977.9333

Laguna

At centerline of church at portico.
1952 Black Worden Meter 10e g 977.7898

Loto

Inter-American Agriculture Institute at BM #99.
1952 Black Worden Meter 10e g 978.0699

Palmares

Catholic church at east side of plaza, 25 feet west of entrance, at same level.
1952 Black Worden Meter 10e g 977.9831

Paraisco

BM #263.
1952 Black Worden Meter 10e g 977.9084

Puntarenas

North side of railroad station on steps at BM CF 2.
1952 Black Worden Meter 10e g 978.2351

San Isidro

Astronomical and geodetic station on plaque.
1952 Black Worden Meter 10e g 977.9938

Costa Rica (continued)

San Juan Naranjo

At northeast abutment of culvert on old BM
plaque now removed.

1952 Black Worden Meter 10e g 977.9431

San Ramon

Southwest corner of Catholic church at BM #222.

1952 Black Worden Meter 10e g 977.9727

South Barranca Base

At BM.

1952 Black Worden Meter 10e g 978.2141

Varablanca

BM #386.

1952 Black Worden Meter 10e g 977.6364

Volcano de Irazu

BM #38C.

1952 Black Worden Meter 10e g 977.4755

Zareero

Catholic church at centerline of church at
church door on west side of plaza.

1952 Black Worden Meter 10e g 977.8143

National Pendulum Base (San Jose) CRp.

1952 Black Worden Meter 10e g 977.9516

Cuba

Guantanamo Bay Naval Base

1. Naval Air Station, at terminal to which control tower is affixed. Station is at canopy farthest from control tower end and at field end of canopy.

1951 Bonini Worden Meter 10e g 978.7470

2. Air Officers Quarters, on first floor in center of room 6.

1951 Bonini Worden Meter 10e g 978.7495

3. Wharf (Pier) Baker, underneath sign "62" on building 62 (smoke stack building) at center of wharf, 100 feet from edge of wharf and 10 feet above water level.

1951 Bonini Worden Meter 10e g 978.7506

Guatemala

Guatemala City

Airport at middle of wall inside outgoing
customs room entering from waiting room.

1949	Harding	Worden Meter 10c	g	977.9837*
1952	Black	Worden Meter 10e	g	977.9849

Honduras

Ticontin

Municipal Airport, in front of gate No. 5,
fifteen feet south of door at twelve foot
pillar.

1952	Black	Worden Meter 10e	g	978.0884
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Nicaragua

Managua

Airport to left of field entrance to terminal
waiting room.

1949	Harding	Worden Meter 10c	g	978.2885*
1952	Black	Worden Meter 10e	g	978.2891

Panama Canal Zone

Balboa

1. Albrook AFB, in MATS terminal at runway end of
of "To Planes" corridor.
1949 Harding Worden Meter 10c g 978.2444
Corrected to g 978.2452
1950 Harding Worden Meter 41b g 978.2454
1950 Harding Worden Meter 41b g 978.2452
1950 Muckenfuss Worden Meter 10e g 978.2449
1951 Bonini Worden Meter 10e g 978.2452
*1952 Black Worden Meter 10e g 978.2452

* Base value used for 1952 survey.
2. Albrook Field, Canal Zone Library, on first
floor of library west of inner electric eye
door and pillar by stairs.
1949 Harding Worden Meter 10c g 978.2435*
1950 Harding Worden Meter 41b g 978.2435
3. Albrook AFB, Officers' Club, Room 9.
1952 Black Worden Meter 10e g 978.2407
4. Balboa YMCA, Commander Shelton's Pendulum base
in basement storeroom.
1949 Harding Worden Meter 10c g 978.2418*
1950 Harding Worden Meter 41b g 978.2425
1950 Harding Worden Meter 41b g 978.2418
1950 Muckenfuss Worden Meter 10e g 978.2417
1951 Bonini Worden Meter 10e g 978.2418
1952 Black Worden Meter 10e g 978.2416
5. Balboa YMCA, on second floor at left of head of
stairs by wall, underneath light switch.
1951 Bonini Worden Meter 10e g 978.2396
6. Inter-American Geodetic Survey office, on
Roosevelt Ave., Commander Shelton's gravimeter
base in northeast corner of northeast room.
1949 Harding Worden Meter 10c g 978.2418*
1950 Harding Worden Meter 41b g 978.2422
7. 15th Naval District Headquarters, at front
entrance beneath green lamps on right side of
entrance at top of steps.
1951 Bonini Worden Meter 10e g 978.2390
1952 Black Worden Meter 10e g 978.2391

Panama Canal Zone

Balboa (continued)

8. Navy BOQ, across street from 15th Naval District headquarters, on pavement outside entrance, street level.
1949 Harding Worden Meter 10c g 978.2389*
1950 Harding Worden Meter 41b g 978.2392
1951 Bonini Worden Meter 10e g 978.2394
9. Pier 15C
1950 Harding Worden Meter 41b g 978.2412
10. Pier Balboa C
1950 Harding Worden Meter 41b g 978.2405
11. Pier 18, at post no. 3, close to Ladies' room on shoreward end, ten feet above sea level.
1951 Bonini Worden Meter 10e g 978.2415
12. Railroad Station, between ticket windows on track side of station, track level.
1951 Bonini Worden Meter 10e g 978.2411
13. Rodman Naval Base, at shore end of center of three concrete piers next to large valve block painted black and yellow.
1951 Bonini Worden Meter 10e g 978.2408

Cerro Gordo (Hill)

1. In station building No. 1 near Pedro Miguel locks.
1949 Harding Worden Meter 10c g 978.1864*
2. In building No. 4.
1949 Harding Worden Meter 10c g 978.1879*

Coco Solo Naval Base

1. Southwest corner of Building No. 92, near end of old pier, No. 1. Pendulum Base.
1948 Woollard Worden Meter 10b g 978.2590
1949 Harding Worden Meter 10c g 978.2586*
1951 Bonini Worden Meter 10e g 978.2583
1952 Black Worden Meter 10e g 978.2596
2. At street door to Building No. 152 (control tower on end) close to NAS operations officer's door.
1951 Bonini Worden Meter 10e g 978.2585
1952 Black Worden Meter 10e g 978.2589

Panama Canal Zone (continued)

Coco Solo Bridge

BM on southwest corner of bridge over Coco Solo River on Isthmus road.

1949 Harding Worden Meter 10c 978.2607*

Cristobal

At Panama Railroad Building, (Captain of the Port Building) on pier side of building underneath old drinking fountain near employees' mens room, on veranda.

1951 Bonini Worden Meter 10e g 978.2563

Gatun Bridge

On northwest curb of bridge over Gatun River on Isthmus road.

1949 Harding Worden Meter 10c g 978.2974*

Madden Bridge

On northwest curb of Madden Bridge over Chagres River on Isthmus road.

1949 Harding Worden Meter 10c g 978.2601*

Naos Island

South end of open shed T-317 at road junction of Naos Island causeway at Army Pier road.

1949 Harding Worden Meter 10c g 978.2361*

Panama City

Airport BM at "Y" in airport road off Panama Isthmus road.

1949 Harding Worden Meter 10c g 978.2551*

Queb Ancha

On northwest curb of bridge of Panama Isthmus road across Queb Ancha branch of Chilibre River.

1949 Harding Worden Meter 10c g 978.2480*

Rio Sucia Bridge

On southeast curb of bridge of Isthmus road at junction of Rio Bonito and Rio Sucia.

1949 Harding Worden Meter 10c g 978.2853*

Tacumen Civilian Airport

1. To right of main entrance to Immigration by passenger waiting fence at TACA entrance

1952 Black Worden Meter 10e g 978.2712

2. To left of customs entrance.

1952 Black Worden Meter 10e g 978.2694

1952 Black Worden Meter 10e g 978.2695

Puerto Rico

Aquadilla

Over BM plaque on step of west entrance to city hall.

1949 Harding Worden Meter 10c g 978.6788*

Cabo Rojo

Over BM in northwest corner of cement platform in front of store on south corner of road junction of Highway 18 and Puerto Real Road.

1949 Harding Worden Meter 10c g 978.6634*

Mayaguez

Northeast corner of old power magazine building just south of Federal prison. Approximate site Lushenes pendulum station USC & GS.

1949 Harding Worden Meter 10c g 978.6663*

Ramey AFB

In MATS waiting room in airport terminal building, just south of street entrance.

1949 Harding Worden Meter 10c g 978.6609*

1951 Bonini Worden Meter 10e g 978.6610

Rincon

Over BM on northwest corner of cement platform of railroad station.

1949 Harding Worden Meter 10c g 978.6555*

San Juan

1. Municipal Airport Terminal at exit to street gate of incoming customs and baggage room.

1949 Harding Worden Meter 10c g 978.6855*

2. "Air Force Terminal" room, to right of door, station is across street from municipal terminal.

1950 Harding Worden Meter 41b g 978.6851

3. House of Representatives, west wing, west of entrance to northwest room in basement.

1950 Harding Worden Meter 41b g 978.6776

Salvador

San Salvador

Airport terminal, in customs waiting room at doorway to men's room.

1949 Harding Worden Meter 10c g 978.1911

1952 Black Worden Meter 10e g 978.1915

Part III

NORTH AMERICAN AREA

Canada

United States

Canada

Newfoundland

Argentia

1. Argentia Naval Air Station, old terminal inside hangar by waiting room door, (Coast Guard hangar)

1950	Harding	Worden Meter 41b	980.8549
1951	Bonini	Worden Meter 10e	980.8543
1952	Woollard	Frost Meter	980.8555
1952	Bonini	Worden Meter 126	980.8545
1953	Woollard	Worden Meter 10e	980.8546
1953	Woollard	Worden Meter 142	980.8549
1953	Woollard	Worden Meter 10f	980.8547
1954	Woollard	Worden Meter 147	980.8552

2. New terminal, just inside lobby at field entrance.

1953	Woollard	Worden Meter 10e	980.8532
1953	Woollard	Worden Meter 142	980.8541
1954	Woollard	Worden Meter 10f	980.8539
1954	Woollard	Worden Meter 147	980.8541

Gander Air Force Base

In southeast corner of Hangar #22 field door, opposite Imperial Esso office beneath electrical switchboard.

1952	Woollard	Frost Meter	980.9598
1952	Bonini	Worden Meter 126	980.9576

United States

Alabama

Birmingham

1. Municipal Airport, four feet east of north-east corner of steel fence around ramps.
1952 Black Worden Meter 10e g 979.5398
2. Municipal Airport, on porch on field side of terminal beneath Eastern Airlines neon sign, one foot above field elevation.
1951 Bonini Worden Meter 10e g 979.5396

Mobile

1. Bates Field, to right of main gate at sidewalk and runway under parapet.
1952 Black Worden Meter 10e g 979.3409
2. Bates Field to left of field entrance to terminal.
1949 Harding Worden Meter 10c g 979.3405*
1950 Harding Worden Meter 10e g 979.3403
1950 Harding Worden Meter 41b g 979.3402
1950 Muckenfuss Worden Meter 10e g 979.3403
1950 Muckenfuss Worden Meter 41b g 979.3406
1951 Bonini Worden Meter 10e g 979.3404
3. Brookley Air Force Base, outside MATS terminal on ground near Gate #1.
1950 Muckenfuss Worden Meter 10e g 979.3552
1950 Muckenfuss Worden Meter 41b g 979.3555
1951 Bonini Worden Meter 10e g 979.3553
1952 Black Worden Meter 10e g 979.3553
4. Brookley Air Force Base, MATS terminal next to baggage room door.
1949 Harding Worden Meter 10c g 979.3551*
1950 Harding Worden Meter 10e g 979.3550
1950 Harding Worden Meter 41b g 979.3548
1951 Bonini Worden Meter 10e g 979.3550
1952 Black Worden Meter 10e g 979.3549

Montgomery

- Municipal Airport, at instrument shack for battery charger of Eastern Airlines.
1952 Black Worden Meter 10e g 979.5108

United States (continued)

District of Columbia

Washington

1. Bureau of Standards, street level to right of main door on west side of east building at foot of steps.

1951	Bonini	Worden Meter 10e	g	980.0976
1952	Woollard	Frost Meter	g	980.0974
2. Bureau of Standards, sub-sub-basement, at foot of steps, pendulum base.

1948	Woollard	Worden Meter 10a	g	980.0997
1950	Harding	Worden Meter 41b	g	980.0994
1951	Bonini	Worden Meter 10e	g	980.0996
1954	Woollard	Worden Meter 10f	g	980.0994
1954	Woollard	Worden Meter 147	g	980.0994
3. Geophysical Laboratory of Carnegie Institute, on top of pendulum pier in basement.

1950	Harding	Worden Meter 41b	g	980.1004
1951	Bonini	Worden Meter 10e	g	980.1006
1954	Woollard	Worden Meter 10f	g	980.1006
1954	Woollard	Worden Meter 147	g	980.1008
4. Geophysical Laboratory of Carnegie Institute, at parking lot level next to BM 21 on south-west corner of building.

1950	Harding	Worden Meter 41b	g	980.1000
1951	Bonini	Worden Meter 10e	g	980.1000
1952	Woollard	Frost Meter	g	980.0998
5. National Airport, Civilian Terminal, at Eastern Airlines Baggage Office at field level on field side of building.

1949	Harding	Worden Meter 10c	g	980.1099
1950	Muckenfuss	Worden Meter 10e	g	980.1098
1950	Harding	Worden Meter 41b	g	980.1098
1951	Woollard	Worden Meter 10e	g	980.1098
1951	Bonini	Worden Meter 10e	g	980.1098
1952	Black	Worden Meter 10e	g	980.1098
1952	Black	Worden Meter 10e	g	980.1098
6. National Airport, Civilian Terminal, on car parking side of terminal, directly beneath "W" in large gold letters of "Washington National Airport" sign, between two pillars.

1951	Bonini	Worden Meter 10e	g	980.1089
1952	Black	Worden Meter 10e	g	980.1090
1954	Woollard	Worden Meter 10f	g	980.1089
1954	Woollard	Worden Meter 147	g	980.1089

United States (continued)

District of Columbia

Washington

7. Commerce Building, on pendulum pier in gravity vault.

1948	Woollard	Worden Meter 10a	g	980.1190
1948	Woollard	Worden Meter 10b	g	980.1190
1949	Harding	Worden Meter 10c	g	980.1190
1950	Harding	Worden Meter 41b	g	980.1190
1950	Muckenfuss	Worden Meter 10e	g	980.1190
1954	Woollard	Worden Meter 10f	g	980.1190
1954	Woollard	Worden Meter 147	g	980.1189

8. Commerce Building, in north driveway off south courts on east side of building on south curb by iron gate. (14th St. side of building)

1950	Harding	Worden Meter 41b	g	980.1182
1950	Muckenfuss	Worden Meter 10e	g	980.1182
1951	Bonini	Worden Meter 10e	g	980.1182
1952	Woollard	Frost Meter	g	980.1182*
1952	Bonini	Worden Meter 126	g	980.1182*
1953	Woollard	Worden Meter 10e	g	980.1182*
1953	Woollard	Worden Meter 142	g	980.1182*
1954	Woollard	Worden Meter 10f	g	980.1182*
1954	Woollard	Worden Meter 147	g	980.1182*

* Base value for 1952, 1953 and 1954 trips to Europe.

9. Union Station, on platform on concourse side to right of gate #4.

1948	Woollard	Worden Meter 10c	g	980.1169
1949	Harding	Worden Meter 10c	g	980.1173
1953	Woollard	Worden Meter 10e	g	980.1174
1953	Woollard	Worden Meter 142	g	980.1175

10. Cosmos Club, 2121 Constitution Avenue, inside foyer, to left of inner entrance door by mail box.

1954	Woollard	Worden Meter 10f	g	980.1138
1954	Woollard	Worden Meter 147	g	980.1139

Florida

Pensacola

1. Saufley Field Naval Air Station, to left of building No. 803A (entrance) beside control tower.

1950	Muckenfuss	Worden Meter 10e	g	979.3587
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2. Municipal Airport, at concourse, under the letter "F" in sign "Pensacola, Florida."

1952	Black	Worden Meter 10e	g	979.3642
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United States (continued)

Georgia

Atlanta

1. To right of Gate #11, at Commercial Field
(temporary Air Terminal),
1950 Muckenfuss Worden Meter 10e g 979.5213
1951 Bonini Worden Meter 10e g 979.5218
2. Inside terminal by barber shop and drinking
fountain.
1951 Bonini Worden Meter 10e g 979.5212
3. Municipal Airport, Gate #1.
1952 Black Worden Meter 10e g 979.5215
1952 Black Worden Meter 10e g 979.5216

Illinois

Chicago

1. Midway Commercial Airport, on floor in hall,
street side of terminal at entrance to Capitol
Airlines.
1948 Woollard Worden Meter 10b g 980.2863
1950 Woollard Worden Meter 41b g 980.2867
1950 Muckenfuss Worden Meter 10e g 980.2863
1951 Woollard Worden Meter 10e g 980.2859
1952 Woollard Worden Meter 10e g 980.2871
1952 Black Worden Meter 10e g 980.2860
1952 Black Worden Meter 14b g 980.2861
1952 Woollard Worden Meter 10e g 980.2859
2. Midway Commercial Airport, old terminal, to
right of passenger entrance.
1952 Black Worden Meter 14b g 980.2832
3. Union Station at Gate #1, Milwaukee Railroad
side.
1953 Woollard Worden Meter 10e g 980.2919
1953 Woollard Worden Meter 142 g 980.2927

United States (continued)

Maryland

Patuxent

1. Naval Air Station, on floor on runway side of terminal building at barrier across lounge.

1948	Woollard	Worden Meter 1Ca	g	980.0262
1950	Harding	Worden Meter 11b	g	980.0258
1950	Muckenfuss	Worden Meter 10e	g	980.0259
1951	Bonini	Worden Meter 10e	g	980.0262
1952	Woollard	Frost Meter	g	980.0263
1952	Bonini	Worden Meter 126	g	980.0254
1953	Woollard	Worden Meter 10e	g	980.0261
1954	Woollard	Worden Meter 10f	g	980.0256
1954	Woollard	Worden Meter 147	g	980.0257
2. Naval Air Station, inside gate at guard house on walk to building #302.

1954	Woollard	Worden Meter 10f	g	980.0205
1954	Woollard	Worden Meter 147	g	980.0207

Massachusetts

Boston

1. South Station, on floor at east end of waiting room in telephone alcove on far side of desk of switchboard operator.

1948	Woollard	Worden Meter 10b	g	980.3979
1949	Woollard	Worden Meter 10c	g	980.3967
1953	Woollard	Worden Meter 10e	g	980.3969
2. North Station at Gate #18.

1953	Woollard	Worden Meter 10e	g	980.4016
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Springfield

1. Railroad Station, on level of platform #1, about 100 feet toward end of platform beyond elevator.

1948	Woollard	Worden Meter 10b	g	980.3614
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2. Railroad Station, at south corner of entrance.

1952	Black	Worden Meter 14b	g	980.3627
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Westover

- Air Force Base (near Chicopee) in corner of alcove of terminal waiting room next to rear door leading across tracks to cafeteria.
- | | | | | |
|------|----------|------------------|---|----------|
| 1943 | Woollard | Worden Meter 10a | g | 980.3557 |
| 1948 | Woollard | Worden Meter 10b | g | 980.3553 |
| 1949 | Harding | Worden Meter 10c | g | 980.3544 |
| 1951 | Woollard | Worden Meter 10e | g | 980.3551 |
| 1951 | Bonini | Worden Meter 10e | g | 980.3554 |
| 1952 | Black | Worden Meter 14b | g | 980.3555 |

United States (continued)

Massachusetts

Winchedon

Railroad Station, north end of station.

1953 Woollard Worden Meter 10e g 980.3512

Michigan

Detroit

Willow Run Airport, beneath Gate #17 sign
under covered walk.

1949	Woollard	Worden Meter 10c	g	980.3189
1950	Harding	Worden Meter 10e	g	980.3182
1950	Harding	Worden Meter 41b	g	980.3183
1950	Muckenfuss	Worden Meter 10e	g	980.3185
1950	Muckenfuss	Worden Meter 41b	g	980.3181
1951	Donini	Worden Meter 10e	g	980.3186
1952	Black	Worden Meter 10e	g	980.3185
1952	Black	Worden Meter 14b	g	980.3189
1954	Woollard	Worden Meter 10f	g	980.3184
1954	Woollard	Worden Meter 147	g	980.3182

New Jersey

Princeton

Guyot Hall at Princeton University, outside
basement entrance.

1952	Woollard	Frost Meter	g	980.1792
1953	Woollard	Worden Meter 10e	g	980.1902

New York

New York

1. La Guardia Airport, on floor of corridor out-
side standby waiting room of American Airlines
at Gangway #4.

1950	Harding	Worden Meter 41b	g	980.2618
1951	Woollard	Worden Meter 10e	g	980.2623

2. La Guardia Airport, Gate #6, Capitol Airlines
Baggage Counter.

1952	Black	Worden Meter 14b	g	980.2818
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3. Idlewild Airport, right side of exit corridor
from customs room to taxi stand.

1953	Woollard	Worden Meter 10e	g	980.2265
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United States (continued)

New York

New York

4. Grand Central Railroad Station, on floor in corner of concourse between gates leading to tracks 30 and 32.

1948	Woollard	Worden Meter 10b	g	980.2672
1950	Harding	Worden Meter 41b	g	980.2682
1953	Woollard	Worden Meter 10e	g	980.2678
5. Northwest and Capitol Airlines ticket office across from Grand Central Station, Air Terminal.

1952	Black	Worden Meter 14b	g	980.2678
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6. Pennsylvania Station, on floor in main lobby at base of steps leading up to 31st Street and to right of office door of Pennsylvania Railroad Travel Bureau Office.

1948	Woollard	Worden Meter 10b	g	980.2663
1949	Harding	Worden Meter 10c	g	980.2653
1952	Black	Worden Meter 14b	g	980.2665

Palisades

- Lamont Observatory in gravity room of basement, on the floor.
- | | | | | |
|------|----------|------------------|---|----------|
| 1949 | Woollard | Worden Meter 10c | g | 980.2583 |
| 1952 | Woollard | Frost Meter | g | 980.2597 |
| 1952 | Woollard | Worden Meter 10e | g | 980.2591 |

Ohio

Cleveland

1. Municipal Airport at Gate #6 on runway side.

1948	Woollard	Worden Meter 10b	g	980.2321
1950	Harding	Worden Meter 10e	g	980.2319
1950	Harding	Worden Meter 41b	g	980.2318
1950	Mackenfuss	Worden Meter 41b	g	980.2316
1951	Bomini	Worden Meter 10e	g	980.2321
1954	Woollard	Worden Meter 10f	g	980.2321
1954	Woollard	Worden Meter 147	g	980.2316
2. Municipal Airport, to right of Gate #3.

1952	Black	Worden Meter 14b	g	980.2323
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United States (continued)

Pennsylvania

Pittsburgh

1. Allegheny County Airport, on runway to left of Gate #5 leading to terminal building.

1948	Woollard	Worden Meter 1Cb	g	980.0901
1950	Harding	Worden Meter 10e	g	980.0893
1950	Harding	Worden Meter 41b	g	980.0893
1950	Muckenfuss	Worden Meter 10e	g	980.0896
1950	Muckenfuss	Worden Meter 41b	g	980.0891
1951	Bonini	Worden Meter 10e	g	980.0895

2. Greater Pittsburgh Airport, at Gate # 9a,

1954	Woollard	Worden Meter 10f	g	980.0992
1954	Woollard	Worden Meter 147	g	980.0992

Wisconsin

Madison

1. University of Wisconsin, Science Hall, outside basement Room #7.

1949	Harding	Worden Meter 10c	g	980.3677
1950	Harding	Worden Meter 10e	g	980.3685
1950	Harding	Worden Meter 41b	g	980.3684
1950	Harding	Worden Meter 41b	g	980.3681
1950	Muckenfuss	Worden Meter 10e	g	980.3683
1950	Muckenfuss	Worden Meter 41b	g	980.3682
1951	Woollard	Worden Meter 10e	g	980.3681
1951	Bonini	Worden Meter 10e	g	980.3686
1952	Woollard	Worden Meter 10e	g	980.3685
1952	Black	Worden Meter 10e	g	980.3683
1952	Black	Worden Meter 10e	g	980.3685
1952	Black	Worden Meter 14b	g	980.3684
1953	Woollard	Worden Meter 10e	g	980.3684
1953	Woollard	Worden Meter 142	g	980.3685
1954	Woollard	Worden Meter 10f	g	980.3684
1954	Woollard	Worden Meter 147	g	980.3685

2. Milwaukee Railroad Station, on floor of waiting room between north and south doors at west end of waiting room.

1953	Woollard	Worden Meter 10e	g	980.3684
1953	Woollard	Worden Meter 142	g	980.3683

3. Milwaukee Railroad Station, at water lines beyond end of express company office at end of platform and on concrete slab.

1951	Woollard	Worden Meter 10e	g	980.3684
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United States (continued)

Wisconsin

Madison

4. Truax Field, on sidewalk at roadway side of terminal building, main entrance.

1950	Harding	Worden Meter 41b	g	980.3719
1951	Bonini	Worden Meter 10e	g	980.3724
1952	Woollard	Worden Meter 10e	g	980.3723
1952	Black	Worden Meter 10e	g	980.3719
1952	Black	Worden Meter 10e	g	980.3720
1952	Black	Worden Meter 14b	g	980.3720
1954	Woollard	Worden Meter 10f	g	980.3721
1954	Woollard	Worden Meter 147	g	980.3719

Milwaukee

1. Milwaukee Railroad Station, in corner by Gate #4, next to building, at track level.

1953	Woollard	Worden Meter 10e	g	980.3695
1953	Woollard	Worden Meter 142	g	980.3697

2. Mitchell Field, by cornerstone near Gate #5 on field side.

1951	Bonini	Worden Meter 10e	g	980.3604
1952	Black	Worden Meter 10e	g	980.3593
1952	Black	Worden Meter 10e	g	980.3600
1952	Black	Worden Meter 14b	g	980.3603

Part IV

SOUTH AMERICAN AREA

Argentina

Bolivia

Brazil

British Guiana

Chile

Colombia

Dutch Guiana

Ecuador

French Guiana

Paraguay

Peru

Uruguay

Venezuela

Note: Values marked with * are revised to conform
to calibration based on Cambridge Pendulums.

Argentina

Bahia Blanca Buenos Aires

S.A. 110

1. Airport, 10 meters north of Airlines Building
and 2 meters north of base of antenna tower.
1952 Black Worden Meter 10e g 980.0696
1952 Black Worden Meter 10e g 980.0694
2. Railroad Station at BM #1008.
1952 Black Worden Meter 10e g 980.0836
3. School #2, Valentin del Gado.
1952 Black Worden Meter 10e g 980.0819

Buenos Aires Buenos Aires

S.A. 100

1. Aeropuerto Pistarini, southwest corner and under parapet at restaurant.
1952 Black Worden Meter 10e g 979.7334
1952 Black Worden Meter 10e g 979.7334
2. Aeropuerto Pistarini, about 4 meters northwest of Gate #3 in triangle of grass between side-walks beside flat concrete cover.
1952 Black Worden Meter 10e 979.7338
1952 Black Worden Meter 10e 979.7337
3. Aeropuerto Pistarini, at Naval Mission Maintenance shops 200 yards north of #2 station and 200 yards west of #1.
1952 Black Worden Meter 10e g 979.7335
4. Moron Iglesia (church)
1949 Harding Worden Meter 10c g 979.7070*
5. Municipal Airport, at base of radio antenna.
1952 Black Worden Meter 10e g 979.7055
1952 Black Worden Meter 10e g 979.7057
6. Municipal Airport, at Baglietto's station.
1952 Black Worden Meter 10e g 979.7054
7. Pilar de Direccion General del Servicio Meteorologico National Villa Ortazar. Pendulum Base.
1949 Harding Worden Meter 10c 979.7077 *
1952 Black Worden Meter 10e 979.7078
8. Pilar de Gravidad absoluta en la instalaciones Alvarez Condarco de ICM, 1 meter towards door at floor level.
1952 Black Worden Meter 10e 979.7065

Argentina

Buenos Aires (continued)

9. IGM Pilar de Gravidad de Potsdam.
1952 Black Worden Meter 10e g 979.7046
 10. Policia Caminera, north point of San Justo
Base Line.
1949 Harding Worden Meter 10c g 979.7114*
 11. Trans Radio Station, across highway opposite
Trans Radio Road.
1949 Harding Worden Meter 10c g 979.7292*
1949 Harding Worden Meter 10c g 979.7292*
- Comodoro Rivadavia Comodoro Rivadavia
S.A. 112
1. Airport, southeast corner of main building on
sidewalk.
1952 Black Worden Meter 10e g 980.6636**
 2. YPF warehouse, second building from main en-
trance to area in basement at first pillar.
1952 Black Worden Meter 10e g 980.6835**

Cordoba

Cordoba

S.A. 103

1. Airport, east entrance to basement at corner
of sidewalk.
1952 Black Worden Meter 10e g 979.3285
1952 Black Worden Meter 10e g 979.3285
2. Astronomic Observatory, in basement at gravity
pillar.
1949 Harding Worden Meter 10c g 979.3402*
1952 Black Worden Meter 10e g 979.3433
3. Parque Sarmiento.
1949 Harding Worden Meter 10c g 979.3440

Jujuy

Jujuy

S.A. 107

- Airport, at entrance to Aerolineas Argentinas
Office.
1952 Black Worden Meter 10e g 978.4652
1952 Black Worden Meter 10e g 978.4654

La Plata

Cordoba

S.A. 101, A.16

- Observatory, Pendulum Station.
1949 Harding Worden Meter 10c g 979.7534*
1952 Black Worden Meter 10e g 979.7534
1952 Black Worden Meter 10e g 979.7534

** \pm 0.3 mgals uncertainty.

Argentina (continued)

Mar del Plata	Buenos Aires
S.A. 119	
1. Airport, passenger entrance at door under parapet leading to car stop.	
1952 Black	Worden Meter 10e g 980.0198 $\frac{1}{2}$
2. Plaza Rocha, pillar of IGM, Baglietto Station.	
1952 Black	Worden Meter 10e g 980.0353 $\frac{1}{2}$
3. Hotel Soldini, 2523 Moreno, 3 feet inside door, IGM pendulum station.	
1952 Black	Worden Meter 10e g 980.0385 $\frac{1}{2}$
Merlo	Buenos Aires
A-3	
Railroad Station, east end at street.	
1949 Harding	Worden Meter 10c g 979.7110*
Moreno	Buenos Aires
A-2	
Railroad Station, west end Boulevard al Carta.	
1949 Harding	Worden Meter 10c g 979.7072*
Oran	Salta
S.A. 108	
Airport, southeast corner of main building on checkered walk.	
1952 Black	Worden Meter 10e g 978.6402
1952 Black	Worden Meter 10e g 978.6403
Pergamino	Buenos Aires
A-7	
Railroad Station.	
1949 Harding	Worden Meter 10c g 979.6296*
Pilar	Buenos Aires
A-5	
Railroad Station.	
1949 Harding	Worden Meter 10c g 979.6940*
Puerto Deseado	Comodoro Rivadavia
S.A. 113	
Airport, at door to restroom.	
1952 Black	Worden Meter 10e g 980.8590
Rio Cuarto	Cordoba
A-12	
Railroad Station.	
1949 Harding	Worden Meter 10c g 979.4854*

\pm 0.3 mgals uncertainty.

Argentina (continued)

Rio Gallegos Santa Cruz
S.A. 116

1. Infraestuntare Airport, at southeast corner of
radio shack.
1952 Black Worden Meter 10e g 981.2048†
2. Aerolineas Argentinas, southwest corner of
restaurant.
1952 Black Worden Meter 10e g 981.2026†
3. National School #1, west side of steps to
entrance.
1952 Black Worden Meter 10e g 981.2128†

Rio Grande Tierra del Fuego
S.A. 117

- Aeropuerto de Marina, southeast corner of
waiting-room.
1952 Black Worden Meter 10e g 981.4354?
1952 Black Worden Meter 10e g 981.4331?

Rosario Santa Fe
A-17

- School Basement.
1949 Harding Worden Meter 10c g 979.5652*

Salta Salta
S.A. 106

- Airport, southwest corner of building at patio.
1952 Black Worden Meter 10e g 978.5007
1952 Black Worden Meter 10e g 978.5008

San Antonio de Areco Buenos Aires
A-6

- Railroad Station.
1949 Harding Worden Meter 10c g 979.6791

San Julian Santa Cruz
S.A. 114

- Airport, southwest corner of Aero Club shack.
1952 Black Worden Meter 10e g 981.0131†

San Miguel Buenos Aires
A-1

- Railroad Station, nine meters from west end.
1949 Harding Worden Meter 10c g 979.7027*

† 0.3 mgals uncertainty.

Argentina (continued)

Santa Cruz Santa Cruz
S.A. 115

Airport, northeast corner of Airlines shack.
1952 Black Worden Meter 10e g 981.0463

Santiago del Estero Santiago del Estero
S.A. 104

Airport, southeast corner of main building.
1952 Black Worden Meter 10e g 979.1009

Tartagal Salta
S.A. 109

Airport, southeast corner of Meteorology House
on walk.
1952 Black Worden Meter 10e g 978.5959

Temperley Buenos Aires
A-4

On street outside of pendulum base.
1949 Harding Worden Meter 10c g 979.7306*

Trelew Chubut
S.A. 111

1. Airport, centerline of west side of sidewalk.
1952 Black Worden Meter 10e g 980.4544
2. Railroad Station, street side level with tracks.
1952 Black Worden Meter 10e g 980.4637

Tucuman Tucuman
S.A. 105

Airport, southwest corner of building at car
shelter.
1952 Black Worden Meter 10e g 978.9088
1952 Black Worden Meter 10e g 978.9087

Ushuaia Tierra del Fuego
S.A. 118

1. Gravity station at the office of the chief of
police.
1952 Black Worden Meter 10e g 981.4856*
2. Penitentiary, cellblock B, 29 meters north of
pendulum base.
1952 Black Worden Meter 10e g 981.5047*
3. Naval Port, in front of the Casino de Salterras.
1952 Black Worden Meter 10e g 981.4843*

* ± 0.3 mgals uncertainty.

Argentina

Ushuaia (continued)

4. Airport, Baglietto's Station.

1952 Black Worden Meter 10c g 981.4847*

A-8

Santa Fe

Bridge, 288-289 km from Buenos Aires on Route 8.
1949 Harding Worden Meter 10c g 979.6293*

A-9

Santa Fe

Culvert, 420.7 km from Buenos Aires on Route 8,
on east side of culvert.
1949 Harding Worden Meter 10c g 979.5950*

A-10

Santa Fe

Culvert, 488.3 km from Buenos Aires on Route 8.
1949 Harding Worden Meter 10c g 979.5872*

A-11

Cordoba

Road junction, 559 km from Buenos Aires on Route 8.
1949 Harding Worden Meter 10c g 979.5532*

A-13

Cordoba

Bench Mark PF 55 N 9.
1949 Harding Worden Meter 10c g 979.4045*

A-18

Santa Fe

Bridge culvert, 354.6 km from Buenos Aires on
Route 8.
1949 Harding Worden Meter 10c g 979.6239*

Bolivia

La Paz

S.A. 82

La Paz

1. Airport, at junction of sidewalk and runway
leading to Braniff Building.

1952 Black Worden Meter 10c g 977.3551

2. Panagra Terminal at junction of runway and side-
walk.

1952 Black Worden Meter 10c g 977.3519

Santa Cruz

Santa Cruz

S.A. 83

Airport, at gate leading to Braniff Airlines
shack.

1952 Black Worden Meter 10c g 978.3663

* ± 0.3 mgals uncertainty.

Brazil

Alegrete Rio Grande do Sul
S.A. 167
 Airport, at fence and sidewalk.
 1952 Black Worden Meter 10e g 979.2941

Aracaju Sergipe
S.A. 179
 Airport, at wind sock.
 1952 Black Worden Meter 10e g 978.2142

Aracati Ceara
S.A. 186
 Airport, 30 yards north of wind sock.
 1952 Black Worden Meter 10e g 978.1005

Aracatupa Sao Paulo
S.A. 128
 Airport, at baggage ramp at southeast corner
 of main building.
 1952 Black Worden Meter 10e g 978.5823
 1952 Black Worden Meter 10e g 978.5822

Aragarcas Goias
S.A. 147
 Airport, at parapet shelter on left side of
 arbor.
 1952 Black Worden Meter 10e g 978.3225

Araguaia Goias
S.A. 156
 Airport, at gate leading to first tower Aereo
 Radio ZW-AA.
 1952 Black Worden Meter 10e g 978.0482

Assu Rio Grande do Norte
S.A. 184
 Airport, 20 yards south of southwest corner of
 building.
 1952 Black Worden Meter 10e g 978.0865

Bage Rio Grande do Sul
S.A. 171
 Airport, at entrance to Administration Building,
 ground level.
 1952 Black Worden Meter 10e g 979.4141

Brazil (continued)

Bauru Sao Paulo
S.A. 131

"Praca Principal" centerline of east side on
sidewalk.
1952 Black Worden Meter 10e g 978.6135

Belem Para
S.A. 162

1. Val de Cans Airport, inside control tower building, first door to right of main entrance from field, next to DAC desk.
1951 Bonini Worden Meter 10e g 978.0354
2. Pan American Airways terminal, in arcade between administration offices and restaurant, about 500 feet from control tower building.
1949 Harding Worden Meter 10c g 978.0355 *
1951 Bonini Worden Meter 10e g 978.0352
3. Fuersas Aereas de Brazil, northeast corner of maintenance shack.
1952 Black Worden Meter 10e g 978.0383
4. Casino Hotel, apartment #4.
1952 Black Worden Meter 10e g 978.0375

Belo Horizonte Minas Gerais
S.A. 144

Airport, southwest corner of junction of west
sidewalk and ramp.
1952 Black Worden Meter 10e g 978.4030
1952 Black Worden Meter 10e g 978.4030

Bocucatu Sao Paulo
S.A. 133

"Praca Col. Moura", 50 feet north of entrance
on sidewalk.
1952 Black Worden Meter 10e g 978.5792

Brasileia Acre
S.A. 200

Airport, at parking ramp, field level.
1952 Black Worden Meter 10e g 978.1595

Cacapava Sao Paulo
S.A. 126

At junction of Rio de Janeiro to San Paulo
highway and road west to Cacapava at Esso
Station.
1952 Black Worden Meter 10e g 978.6514

Brazil (continued)

Caceres Mato Grosso
S.A. 190

Airport, centerline of warehouse, field side.
1952 Black Worden Meter 10e g 978.3992

Campo Grande Mato Grosso
S.A. 138

1. Fuersas Aereas de Brazil Airport, at base of west steps to administration building from field side.
1952 Black Worden Meter 10e g 978.5084
2. Municipal Airport, at entrance to gasoline pump.
1952 Black Worden Meter 10e g 978.5020

Campos Rio de Janeiro
S.A. 172

Airport, 40 meters due south of southwest corner of hangar.
1952 Black Worden Meter 10e g 978.7345

Canavieras Bahia
S.A. 176

Airport, 20 yards north of northeast corner of Fuersas Aereas de Brazil house.
1952 Black Worden Meter 10e g 978.4224

Caravelas Bahia
S.A. 174

Airport, on east wall of terminal at aircraft parking ramp.
1949 Harding Worden Meter 10c g 978.5283
1952 Black Worden Meter 10e g 978.5286

Carolina Goias
S.A. 157

Fuersas Aereas de Brazil Airport, at radio shack.
1952 Black Worden Meter 10e g 978.0495

Conchas Sao Paulo
S.A. 134

"Praca Principal", 50 feet north of center line of west side on sidewalk.
1952 Black Worden Meter 10e g 978.6629

Brazil (continued)

Cruz Alta	Rio Grande do Sul
S.A. 165	
Airport, at base of highest radio antenna.	
1952 Black	Worden Meter 10e g 979.0786
Cruzeiro do Sul	Acre
S.A. 197	
Airport, at parking ramp, field level.	
1952 Black	Worden Meter 10e g 978.1115
Cuiaba	Mato Grosso
S.A. 189	
Airport, at northeast corner of small hangar at gas dump.	
1952 Black	Worden Meter 10e g 978.3616
Curitiba	Parana
S.A. 122	
Airport, on porch at entrance, 3 feet higher than ground and 15 yards from Gate "A".	
1952 Black	Worden Meter 10e g- 978.7919
1952 Black	Worden Meter 10e g 978.7926
1952 Black	Worden Meter 10e g 978.7913
Esplanada	Bahia
S.A. 178	
Airport, 10 yards north of gate to administration building.	
1952 Black	Worden Meter 10e g 978.2639
Fazenda Firme	Mato Grosso
S.A. 141	
At main house in guest room.	
1952 Black	Worden Meter 10e g 978.6064
Fazenda San Juan de Piquiri	Mato Grosso
Airport, at gate leading to house from runway.	
1952 Black	Worden Meter 10e g 978.4838
Florianopolis	Santa Catarina
S.A. 163	
Airport, southwest corner of administration building, 8 feet south of door to weather room.	
1952 Black	Worden Meter 10e g 979.1360

Brazil (continued)

Formosa Minas Gerais

S.A. 150

Airport, northeast corner of storage shack,
120 meters south of main building.

1952 Black Worden Meter g 978.1165

Forteleza Ceara

S.A. 187

1. Airport terminal room, in corner between Panair
baggage counter and curio stand in waiting room.

1949 Harding Worden Meter 10c g 978.0848*

1952 Black Worden Meter 10e g 978.0845

2. Fuersas Aereas de Brazil, 20 yards south of
center line of main hangar.

1952 Black Worden Meter 10e g 978.0854

Forte Principe Guapore

S.A. 192

Airport, at concrete well for gasoline with
steel top at north end of runway.

1952 Black Worden Meter 10e g 978.3005

Goiania Goias

S.A. 146

Airport, at junction of sidewalk and ramp.

1952 Black Worden Meter 10e g 978.2382

1952 Black Worden Meter 10e g 978.2382

Grajau Maranhao

S.A. 159

Airport, at junction of ramp and road to shacks.

1952 Black Worden Meter 10e g 977.9879

Gramacho Rio de Janeiro

District Federal, northeast corner of east
station platform of railroad station.

1949 Harding Worden Meter 10c g 978.7895*

Guajara Mirim Guapore

S.A. 193

Airport, at Cruzeiro do Sul Airlines house steps.

1952 Black Worden Meter 10e g 978.2202

Guaratingueta Sao Paulo

S.A. 125

Iglesia San Antonio at base of steps under
statue of St. Marcos.

1952 Black Worden Meter 10e g 978.6372

Brazil (continued)

Ignassu Falls	Parana
S.A. 121	
Airport, at end of hedge leading to plane ramp at field side.	
1952 Black	Worden Meter 10e g 978.9217
Ilheus	Bahia
S.A. 177	
Airport, 100 yards south of southeast corner of hangar.	
1952 Black	Worden Meter 10e g 978.4636
Imperatiz	Maranhao
S.A. 160	
Airport, at wind sock.	
1952 Black	Worden Meter 10e g 978.0226
Itu	Sao Paulo
S.A. 127	
At statue on highway across street from "Reg- imento Deodero."	
1952 Black	Worden Meter 10e g 978.6633
Joao Pessoa	Paraiba
S.A. 182	
Santa Rita Airfield, about halfway between runway and wind sock.	
1949 Harding	Worden Meter 10c g 978.1464 *
1952 Black	Worden Meter 10e g 978.1471
Lencois	Sao Paulo
S.A. 132	
20 feet north of northeast corner of public cemetery on highway on south side of turn.	
1952 Black	Worden Meter 10e g 978.6140
Lins	Sao Paulo
S.A. 129	
"Praca Municipal" at west side, 10 feet above street at junction of sidewalks.	
1952 Black	Worden Meter 10e g 978.6084
Livramento	Rio Grande do Sul
S.A. 170	
Airport, at gate leading to administration building.	
1952 Black	Worden Meter 10e g 979.3371

Brazil (continued)

Lucas Rio de Janiero
Southwest corner of railroad station, small
town north of Rio de Janeiro.
1949 Harding Worden Meter 10c g 978.7984*

Maceio Alagoas
S.A. 181
Airport, at steps leading to operations building
Fuersas Aereas de Brazil, 10 yards west of
metecrology shack.
1952 Black Worden Meter 10e g 978.1457

Manaos Amazonas
1. Airport, at north end of cement walk to terminal.
1949 Harding Worden Meter 10c g 978.0237*

2. Cruzeiro do Sul Pensao, inside court entrance
on wall by corner of house.
1949 Harding Worden Meter 10c g 978.0324*

Maraba Para
S.A. 161
Airport, at radio station Fuersas Aereas de Brazil.
1952 Black Worden Meter 10e g 978.0397

Mossoro Rio Grande do Norte
S.A. 185
Airport, 70 yards south of southeast corner of
hangar.
1952 Black Worden Meter 10e g 978.0952

Natal Rio Grande do Norte
S.A. 183
1. Airport terminal, north of baggage and customs
field entrance in corner of Flota Aerea Mer-
cante Argentine counter.
1949 Harding Worden Meter 10c g 978.1180*

2. Fuersas Aereas do Brazil Airport, at main
entrance of National Airmail.
1952 Black Worden Meter 10e g 978.1175

Paracatu Minas Gerais
S.A. 149
Airport, northeast corner of hangar.
1952 Black Worden Meter 10e g 978.2629

Brazil (continued)

Parana	Goiás			
S.A. 151				
	Airport, at wind sock.			
	1952 Black	Worden Meter 10e	g	978.1732
Pedro Alfonso	Goiás			
S.A. 155				
	Airport, northeast corner of storage shack.			
	1952 Black	Worden Meter 10e	g	978.0983
Peixe	Goiás			
S.A. 152				
	Airport, at gate leading to road and storage house.			
	1952 Black	Worden Meter 10e	g	978.2013
Penedo	Alagoas			
S.A. 180				
	Airport, 40 yards north of gate to administration building.			
	1952 Black	Worden Meter 10e	g	978.1821
Petropolis	Rio de Janeiro			
1.	Railroad station in the southwest corner of main waiting room.			
	1949 Harding	Worden Meter 10c	g	978.5976 *
2.	Junction of Teresopolis and Petropolis roads, in front of police hut.			
	1949 Harding	Worden Meter 10c	g	978.6123 *
Pirajui	Sao Paulo			
S.A. 130				
	"Praca Principal", northeast corner, 10 meters south of corner on sidewalk.			
	1952 Black	Worden Meter 10e	g	978.6080
Porto Alegre	Rio Grande do Sul			
S.A. 145				
1.	Sao Joad Field, on runway end of brick wall to Panagra customs shack.			
	1949 Harding	Worden Meter 10c	g	979.3116
	1952 Black	Worden Meter 10e	g	979.3120
2.	Municipal Airport, 20 feet west of northwest corner of headquarters building.			
	1952 Black	Worden Meter 10e	g	979.3179
	1952 Black	Worden Meter 10e	g	979.3179

Brazil (continued)

Porto Nacional Goias

S.A. 153

Airport, at gate of Fuersas Aereas de Brazil
gas dump.

1952 Black Worden Meter 10e g 978.1638

Porto Seguro Bahia

S.A. 175

Airport, 20 yards west of centerline of building.

1952 Black Worden Meter 10e g 978.4674?

1952 Black Worden Meter 10e g 978.4686?

Porto Velho Guapore

S.A. 194

Airport, at concrete well for gasoline with
steel cover.

1952 Black Worden Meter 10e g 978.1477

Quarai Rio Grande do Sul

Airport, 20 yards west of administration.
building.

1952 Black Worden Meter 10e g 979.3335

Recife Pernambuco

S.A. 136

1. Airport terminal, runway end of orient and
lattice wall extending out from Ministerio
Aeronautica and Air Police entrance to terminal
from field.

1949 Harding Worden Meter 10c g 978.1727

2. Airport, at base of control tower.

1952 Black Worden Meter 10e g 978.1711

1952 Black Worden Meter 10e g 978.1709

1952 Black Worden Meter 10e g 978.1720

Resende Rio de Janeiro

S.A. 124

At junction of road south to town at northwest
corner on sidewalk at 10 meters east of sign
"Proibido Esclacionar Zona Militar."

1952 Black Worden Meter 10e g 978.6414

Rio Branco Acre

S.A. 195

Airport, at cargo shelter.

1952 Black Worden Meter g 978.1617

Brazil (continued)

Rio de Janeiro

Rio de Janeiro

S.A. 120

1. Galeao Airport, at southwest corner of new international terminal.
1952 Black Worden Meter 10e g 978.8000
2. Galeao Airport, at field exit to cab stand from baggage and customs room for incoming passengers.
1949 Harding Worden Meter 10e g 978.7986*
1951 Bonini Worden Meter 10e g 978.7983
1952 Black Worden Meter 10e g 978.7989
3. Santos Dumont Airport, street entrance to terminal at base of sixth pillar from north side, control tower end.
1949 Harding Worden Meter 10c g 978.8098*
1951 Bonini Worden Meter 10e g 978.8093
1952 Black Worden Meter 10e g 978.8102
4. SGE, base elevation pillar at northeast corner of grounds.
1952 Black Worden Meter 10e g 978.8007
5. Miramar Palace Hotel, sidewalk to left of entrance to hotel.
1951 Bonini Worden Meter 10e g 978.8190
6. Observatorio Nacional, 586 General Bruce St., Main Administration Building, in basement in the seismograph room on the seismic pillar floor level. Shelton Pendulum Base.
1949 Harding Worden Meter 10c g 978.8060*
1951 Bonini Worden Meter 10e g 978.8056
7. Hotel Riviera, to left of ground floor entrance from beach, street level.
1949 Harding Worden Meter 10c g 978.8197*
1951 Bonini Worden Meter 10e g 978.8194
8. KM-0 at Kmo-Lgo do Compainho on road to Sao Paulo.
1949 Harding Worden Meter 10c g 978.8033*

Salvador

Bahia

S.A. 135

1. Ipitangia Airport, at Panair parking ramp end of walk leading to small building situated northeast of terminal.
1949 Harding Worden Meter 10c g 978.3462*
1952 Black Worden Meter 10e g 978.3467

Brazil

Salvador (continued)

2. Airport, 50 yards south and 20 yards east of northwest corner of administration building Fuersas Aereas de Brazil.
1952 Black Worden Meter 10e g 978.3466

Santa Maria Rio Grande do Sul
S.A. 164

- Airport, at southeast corner of control tower.
1952 Black Worden Meter 10e g 979.1640

Santarom Para
About four feet from walk in JHS church yard across street from Pan Brazil seaplane fuel pier.
1949 Harding Worden Meter 10c g 978.0579

Saomborge Rio Grand do Sul
S.A. 166
Airport, 20 feet west of gate to administration building.
1952 Black Worden Meter 10e g 979.2058

Sao Mateus Espirito Santo
S.A. 173
Airport, 100 yards north of southeast corner of landing strip.
1952 Black Worden Meter 10e g 978.5734

Sao Paulo Sao Paulo
S.A. 123

1. International Airport, at Gate #16.
1952 Black Worden Meter 10e g 978.6521
2. International Airport, at Gate #1.
1952 Black Worden Meter 10e g 978.6523
1952 Black Worden Meter 10e g 978.6523
3. International Airport, 8 feet northeast of old customs building doorway to field.
1949 Harding Worden Meter 10c g 978.6513*
4. Air Base Fuersas Aereas de Brazil, at official's quarters to left of entrance.
1952 Black Worden Meter 10e g 978.6521
5. Campo de Marte Airport, southeast corner of Hangar #1.
1952 Black Worden Meter 10e g 978.6560

Brazil (continued)

Sena Madureira Acre
S.A. 196
 Airport, on runway at ramp, 50 yards east of
 west end of runway.
 1952 Black Worden Meter 10e g 978.1503

Tarauaca Acre
S.A. 198
 Airport, at parking ramp, field level.
 1952 Black Worden Meter 10e g 978.1438

Teffe Amazonas
 On brick retaining wall along Amazon River by
 Pan Brazil seaplane tie point.
 1949 Harding Worden Meter 10c g 978.0499*

Teresopolis Rio de Janiero
 Railroad Station, just inside west entrance
 under "Billetes" window.
 1949 Harding Worden Meter 10c g 978.5766*

Tocantinapolis Goias
S.A. 158
 Airport, at wind sock.
 1952 Black Worden Meter 10e g 978.0474

Tocantinia Goias
S.A. 154
 Airport, at wind sock.
 1952 Black Worden Meter 10e g 978.1123

Tres Lagoas Mato Grosso
S.A. 138
 Airport, at base of Radio Tower, 100 feet south
 of radio shack.
 1952 Black Worden Meter 10e g 978.5736
 1952 Black Worden Meter 10e g 978.5730

Uberlandia Minas Gerais
S.A. 145
 Airport, at new National Airlines building to
 left of field entrance.
 1952 Black Worden Meter 10e g 978.2973

Brazil (continued)

Uruguaiana Rio Grande do Sul
S.A. 168
 Airport, at entrance to administration building
 field side.
 1952 Black Worden Meter 10e g 979.3090

Villa Bella Mato Grosso
S.A. 191
 Airport, 20 yards east of gas dump at end of
 runway.
 1952 Black Worden Meter 10e g 978.3433

Vitoria Espirito Santo
S.A. 137
 Airport, at junction of runway and sidewalk.
 1952 Black Worden Meter 10e g 978.6557
 1952 Black Worden Meter 10e g 978.6555

Xapuri Acre
S.A. 199
 Airport, at parking ramp at field level.
 1952 Black Worden Meter 10e g 978.1932

Xabantina Mato Grosso
S.A. 148
 Airport, at "A" frame for cargo.
 1952 Black Worden Meter 10e g 978.2868

British Guiana

Georgetown
 Atkinson Field, on aircraft parking ramp before
 passenger entrance to terminal.
 1949 Harding Worden Meter 10c g 978.0939*

Chile

Antofagasta Antofagasta
 Airport, beside cement field elevation monument
 on parking ramp about three feet right of pas-
 senger gate to terminal walk.
 1949 Harding Worden Meter 10c g 978.8855*
 1952 Black Worden Meter 10e g 978.8834
 1952 Black Worden Meter 10e g 978.8855

Chile (continued)

Arica

Parapaca

S.A. 99

Airport, 15 feet south of gate leading to
Panagra waiting room at corner of fence.

1952 Black Worden Meter 10e g 978.5135

Santiago

Santiago

S.A. 98

1. Airport, at passenger side of terminal, 5 feet
lower than Harding's station.

1952 Black Worden Meter 10e g 979.4511

1952 Black Worden Meter 10e g 979.4513

1952 Black Worden Meter 10e g 979.4512

2. Airport terminal, in waiting room lobby by
exit to taxi stands.

1949 Harding Worden Meter 10c g 979.4513 *

3. Commander Shelton's pendulum station in basement
of Geographic Militar.

1949 Harding Worden Meter 10c g 979.4314 *

1952 Black Worden Meter 10e g 979.4304

Colombia

Alto de Minas

Antioquia

S.A. 46

Refreshment stand, BM #160 CW5.

1952 Black Worden Meter 10e g 977.5525

Alto El Volador, Sesquile

Cundinamarca

S.A. 72

North edge of salt mine, BM #4T1.

1952 Black Worden Meter 10e g 977.3843

Anserma

Caldas

S.A. 34

Parque Robledo, BM #45CW5

1952 Black Worden Meter 10e g 977.7177

Arcabuca

Boyaca

S.A. 67

BM at main church.

1952 Black Worden Meter 10e g 977.4986

Colombia (continued)

Armenia

Caldas

S.A. 26

1. USC & GS Pendulum Station in the northeast corner of Market building in the last hall, along the southeast side in a rectangular room with a curved corner.
1952 Black Worden Meter 10e g 977.7347
2. Parque Sucre, BM #134 W.
1952 Black Worden Meter 10e g 977.7298

Barbosa

Santander

S.A. 65

BM #1TC4.

1952 Black Worden Meter 10e g 977.6929

Barranquilla

Atlantico

S.A. 4

1. Airport, at Gate #2.
1952 Black Worden Meter 10e g 978.2288
2. Airport terminal, against outside wall between doorway marked "Entrada Internacional," on runway side of terminal.
1949 Harding Worden Meter 10c g 978.2296*

Bogota

Cundinamarca

S.A. 5

1. Municipal Airport, at the centerline of the administration building at the main pillar.
1952 Black Worden Meter 10e g 977.4051
1952 Black Worden Meter 10e g 977.4052
2. Instituto Geografico Militar, at entrance to southwest room where USC & GS made observation.
1952 Black Worden Meter 10e g 977.4072
1952 Black Worden Meter 10e g 977.4072
1952 Black Worden Meter 10e g 977.4071

Bogota - Girador Highway

S.A. 10

BM #32 B-W.

1952 Black Worden Meter 10e g 977.7572

Buenos Aires

Tolima

S.A. 15

BM #69 A-W

1952 Black Worden Meter 10e g 977.8117

Colombia (continued)

Cajamarca	Tolima
S.A. 21	
At main church, 0.1 meter higher than BM #98W.	
1952 Black	Worden Meter 10e g 977.6403
Caldas	Antioquia
S.A. 47	
In park, BM #171 CW5.	
1952 Black	Worden Meter 10e g 977.6931
Calarca	Caldas
S.A. 25	
BM #127 W.	
1952 Black	Worden Meter 10e g 977.7134
Calli	Val del Cauca
Airport terminal, two paces southeast of control tower in center of main lobby.	
1949 Harding	Worden Meter 10c g 977.8229
1952 Black	Worden Meter 10e g 977.8228
Caramanta	Antioquia
S.A. 41	
At Parish Church, 3 meters higher than BM #97CW5.	
1952 Black	Worden Meter 10e g 977.5960
Cerritos	Caldas
S.A. 30	
BM #1CW5.	
1952 Black	Worden Meter 10e g 977.7817
Chicoral	Tolima
S.A. 14	
BM #63 A-W.	
1952 Black	Worden Meter 10e g 977.8539
Cimitarra	Santander
S.A. 62	
BM # 51TC3.	
1952 Black	Worden Meter 10e g 977.9275
Circasia	Caldas
S.A. 27	
In garden of main church, BM #141 W.	
1952 Black	Worden Meter 10e g 977.6606

Colombia (continued)

Cisneros	Antioquia
S.A. 55	
Railroad Station, west corner of the building.	
1952 Black	Worden Meter 10e g 977.8209
Cristalina	Antioquia
S.A. 57	
Railroad Station, near warning marker.	
1952 Black	Worden Meter 10e g 978.0277
El Colegio	Cundinamarca
S.A. 9	
BM #27 A-W.	
1952 Black	Worden Meter 10e g 977.7383
El Ranchito	Antioquia
S.A. 48	
BM #178 CW5.	
1952 Black	Worden Meter 10e g 977.7279
El Roble	Caldas
S.A. 28	
At restaurant, BM #148 W.	
1952 Black	Worden Meter 10e g 977.5794
El Tabor	Caldas
S.A. 36	
BM #63CW5.	
1952 Black	Worden Meter 10e g 977.5967
Fonda Asia	Caldas
S.A. 32	
At intersection of road to Viterbo, BM #24CW5.	
1952 Black	Worden Meter 10e g 977.8532
Fuquene	Cundinamarca
S.A. 74	
1. Island of Santuario, Astro-station #16, Instituto Geografico de Colombia, Station #189, observation at the base of pedestal.	
1952 Black	Worden Meter 10e g 977.4702
2. Island of Santuario on patio of main house.	
1952 Black	Worden Meter 10e g 977.4783

Colombia (continued)

Girador Tolima
S.A. 13

1. Hotel San German, southeast corner of building
in room next to lavatory.
1952 Black Worden Meter 10e g 977.8862
2. BM #54 A-W
1952 Black Worden Meter 10e g 977.8862

Girardota Antioquia
S.A. 52

- At railroad station.
1952 Black Worden Meter 10e g 977.7704

Ibaque Tolima
S.A. 16

1. Parque de Fondador de Ibaque, BM #76 A-W.
1952 Black Worden Meter 10e g 977.7337
2. 15 feet northwest of USC & GS Station at garage
door.
1952 Black Worden Meter 10e g 977.7258

Jordan Santander
S.A. 63

- At the school, BM #81TC3.
1952 Black Worden Meter 10e g 977.7754

La Gran Via Cundinamarca
S.A. 8

- BM #23 A-W.
1952 Black Worden Meter 10e g 977.6357

La Linea Tolima-Caldas
S.A. 23

- BM #112 W.
1952 Black Worden Meter 10e g 977.3493

Las Brisas Caldas
S.A. 40

- BM #90CW5, three meters higher.
1952 Black Worden Meter 10e g 977.6014

La Virginia Caldas
S.A. 31

- Railroad Station, BM #9CW5.
1952 Black Worden Meter 10e g 977.8425

Colombia (continued)

Medellin	Antioquia
S.A. 49	
1. Olaya Herrera Airport, BM #183 CW5.	
1952 Black	Worden Meter 10e g 977.7621
2. Plaza de Berrio, BM #186 CW5.	
1952 Black	Worden Meter 10e g 977.7612
3. University of Antioquia, at door 48-12 at the main building at centerline of top step.	
1952 Black	Worden Meter 10e g 977.7584
Moniquira	Santander
S.A. 66	
Park in front of church.	
1952 Black	Worden Meter 10e g 977.6794
Monitanita	Caldas
S.A. 24	
BM #119 W.	
1952 Black	Worden Meter 10e g 977.5335
Montegrande	Antioquia
S.A. 44	
BM #140 CW5.	
1952 Black	Worden Meter 10e g 977.7897
Perales	Tolima
S.A. 17	
Ibaque Airport, northwest corner of fence.	
1952 Black	Worden Meter 10e g 977.7798
Pereira	Caldas
S.A. 29	
1. La Pobreza church, BM #166 W.	
1952 Black	Worden Meter 10e g 977.7486
2. Matecana Airport, at control tower, BM #170 W	
1952 Black	Worden Meter 10e g 977.7780
Popalito	Antioquia
S.A. 53	
At Railroad Station.	
1952 Black	Worden Meter 10e g 977.7662

Colombia (continued)

Puente Boyaca	Boyaca			
S.A. 70		At monument, BM #35 NEI.		
	1952	Black	Worden Meter 10e	g 977.4313
Puente La Pintada	Antioquia			
S.A. 43		Bridge over the Rio Cauca, BM #128 CW5.		
	1952	Black	Worden Meter 10e	g 977.8912
Puente Narino	Zipaquira-Cundinamarca			
S.A. 77		Bridge over the Rio Neusa, BM #J4-Z.		
	1952	Black	Worden Meter 10e	g 977.4057
Puente Rio San Juan	Santander			
S.A. 60		On east abutment on northeast end of bridge.		
	1952	Black	Worden Meter 10e	g 977.9919
Puerto Arango	Santander			
S.A. 61		Rio Carare Bridge, BM #29 TC3.		
	1952	Black	Worden Meter 10e	g 977.9788
Puerto Berrio	Antioquia			
S.A. 58		Hotel Magdalena, at entrance.		
	1952	Black	Worden Meter 10e	g 978.0297
Puerto Olaya	Santander			
S.A. 59		At Statue, BM #1TC3.		
	1952	Black	Worden Meter 10e	g 978.0311
Q. El Tigre	Cajamarca			
S.A. 19		BM #A89 W.		
	1952	Black	Worden Meter 10e	g 977.6831
Q. Lazaro	Caldas			
S.A. 33		BM #33 CW5.		
	1952	Black	Worden Meter 10e	g 977.8476

Colombia (continued)

Rio Anaime Tolima
S.A. 20
BM #96 W, 0.2 meters higher.
1952 Black Worden Meter 10e g 977.6456

Rio Bermellon Tolima
S.A. 22
BM #107 W.
1952 Black Worden Meter 10e g 977.4942

Rio Coello Tolima
S.A. 18
BM #C 79 W.
1952 Black Worden Meter 10e g 977.7468

Rio Sucio Caldas
S.A. 37
1. Hotel Internacional, at north pillar of main entrance.
1952 Black Worden Meter 10e g 977.6789
2. In park of San Sabatian Church, BM #70 CW5.
1952 Black Worden Meter 10e g 977.6772

San Clemente Caldas
S.A. 35
At main church, BM #54 CW5.
1952 Black Worden Meter 10e g 977.6146

San Jose Antioquia
S.A. 56
Railroad Station at road to the south.
1952 Black Worden Meter 10e g 977.9021

Santa Barbara Antioquia
S.A. 45
At main church, in south corner entrance.
1952 Black Worden Meter 10e g 977.7120

Santiago Antioquia
S.A. 54
Railroad Station, at the point of the pass, at the west mouth of the tunel de la Quiebra.
1952 Black Worden Meter 10e g 977.7772

Colombia (continued)

Soacha	Tolima			
S.A. 6				
	At center of plaza at BM #11 A-W.			
	1952 Black	Worden Meter 10e	g	977.4066
Supia	Caldas			
S.A. 39				
1.	Parque Bolivar, west corner at base of statue.			
	1952 Black	Worden Meter 10e	g	977.7870
2.	On porch of main church, BM #80 CW5.			
	1952 Black	Worden Meter 10e	g	977.7865
Tausa	Cundinamarca			
S.A. 76				
	South corner of main building.			
	1952 Black	Worden Meter 10e	g	977.3554
Tequendoma	Tolima			
S.A. 7				
	Hotel de Salto, BM #16 B-W.			
	1952 Black	Worden Meter 10e	g	977.4427
Tocaima	Tolima			
S.A. 12				
	Railroad Station, BM #44 A-W.			
	1952 Black	Worden Meter 10e	g	977.8525
Tunja	Boyaca			
S.A. 68				
1.	Hotel at main entrance.			
	1952 Black	Worden Meter 10e	g	977.4179
2.	Plaza Bolivar, BM #48 NEI.			
	1952 Black	Worden Meter 10e	g	977.4167
Ubate	Cundinamarca			
S.A. 75				
	West corner of main church.			
	1952 Black	Worden Meter 10e	g	977.4556
Valparaiso	Antioquia			
S.A. 42				
	Iglesia Sta. Ana, north corner, 0.1 meter higher than BM #111 CW5.			
	1952 Black	Worden Meter 10e	g	977.7453

Colombia (continued)

Velez Las Mercedes Santander
S.A. 64

BM #102 TC3.
1952 Black Worden Meter 10e g 977.5014

Villa Pinzon Cundinamarca

S.A. 71

At main church, BM #6 NEI.
1952 Black Worden Meter 10e g 977.3950

Viota

S.A. 11

BM #37 A-W.
1952 Black Worden Meter 10e g 977.8182

Zipaquira Cundinamarca

S.A. 78

At main church, 1.2 meters lower than BM #T2.
1952 Black Worden Meter 10e g 977.3981

Dutch Guiana (Surinam)

Paramaribo

Zandry Field, at runway end of first sidewalk
south of operations tower.

1949 Harding Worden Meter 10c g 978.0500*

Ecuador

Guayaquil

S.A. 1

Airport terminal, north of Panagra operations
doorway on north ramp to runway.

1949 Harding Worden Meter 10c g 978.1412*

1952 Black Worden Meter 10e g 978.1415

1952 Black Worden Meter 10e g 978.1416

Quito

S.A. 81

1. Airport terminal, beside the north door on run-
way side of terminal on Panagra luggage platform.

1949 Harding Worden Meter 10c g 977.2893*

1952 Black Worden Meter 10e g 977.2894

Ecuador (continued)

Quito (continued)

2. Observatorio de Quito, Commander Shelton's
Pendulum station in the Seismograph room in
the basement of the observatory.
1949 Harding Worden Meter 10c g 977.2808*
3. American Embassy, on left (West) side of vestibule
of front entrance.
1949 Harding Worden Meter 10c g 977.2786*

French Guiana

Cayenne

- Rochambeau Field, at parking ramp end of walk
to terminal from field.
1949 Harding Worden Meter 10c g 978.0413*

Paraguay

Asuncion

S.A. 84

- Airport, at southeast corner of building at
passenger entrance.
1952 Black Worden Meter 10e g 978.9600
1952 Black Worden Meter 10e g 978.9599

Peru

Casa Palcoa

Lima

S.A. 90

- Railroad station, centerline of platform.
1952 Black Worden Meter 10e g 977.0416

Chicla

Lima

S.A. 89

- Railroad Station, 30 meters south of southwest
corner.
1952 Black Worden Meter 10e g 977.1271

Chosica

Lima

S.A. 85

- Railroad Station, at northwest corner.
1952 Black Worden Meter 10e g 977.9755

Peru (continued)

- Concepcion Junin
S.A. 95
 Railroad Station, 30 meters north of the
 north side.
 1952 Black Worden Meter 10e g 977.2786
- Huancayo Junin
S.A. 96
 1. 30 meters north of the Railroad Station.
 1952 Black Worden Meter 10e g 977.2868
 2. Instituto Geofisico, Magnetic Station.
 1952 Black Worden Meter 10e g 977.2668
- Iquitos Loreto
 1. Airport terminal, on cement walk to taxi stand
 side of wooden terminal building at base of
 front steps.
 1949 Harding Worden Meter 10c g 978.0898
 2. Street level entrance to Hotel Malecon Palace.
 1952 Harding Worden Meter 10c g 978.0869
- Jauja Junin
S.A. 94
 Railroad Station, 20 meters north of the north
 side.
 1952 Black Worden Meter 10e g 977.2415
- La Oroya Junin
S.A. 92
 Railroad Station at baggage room entrance.
 1952 Black Worden Meter 10e g 977.1387
- Lima Lima
S.A. 3
 1. Airport, inside the field entrance for incoming
 passengers, 20 feet north of stairway leading to
 main lobby and customs.
 1952 Black Worden Meter 10e g 978.2813
 1952 Black Worden Meter 10e g 978.2813
 2. Airport, in terminal directly below passenger
 entrance to station from taxi stand.
 1949 Harding Worden Meter 10e g 978.2829*
 3. Railroad Station, track level at base of steps
 leading overhead to street level.
 1952 Black Worden Meter 10e g 978.2828

Peru (continued)

Matucana	Lima
S.A. 87	
Railroad Station, 30 meters west of northwest corner of station.	
1952 Black	Worden Meter 10e g 977.4499
Pachacayo	Junin
S.A. 93	
Railroad Station, 30 meters north of station.	
1952 Black	Worden Meter 10e g 977.2169
San Bartolome	Lima
S.A. 86	
Railroad Station, centerline of entrance.	
1952 Black	Worden Meter 10e g 977.7240
Talara	Piura
S.A. 2	
Airport, at intersection of runway and sidewalk to administration building.	
1949 Harding	Worden Meter 10c g 978.1363*
1952 Black	Worden Meter 10e g 978.1360
1952 Black	Worden Meter 10e g 978.1363
Tamborague	Lima
S.A. 88	
Railroad Station, 10 meters east of the southeast corner.	
1952 Black	Worden Meter 10e g 977.2711
Tielio	Junin
S.A. 91	
Railroad Station, at highest point of railroad.	
1952 Black	Worden Meter 10e g 976.9263

Uruguay

Montevideo	
Carrasco Field Airport, in bus parking lot in corner between covered walk and main terminal building.	
1949 Harding	Worden Meter 10c g 979.7478*
1952 Black	Worden Meter 10e g 979.7478

Venezuela

Barcelona Anzoategui
Airport, about 200 feet west of new terminal
building at junction of concrete parking ramp,
and black-top taxi ramp.
1949 Harding Worden Meter 10c g 978.1531*

Caracas Federal District
1. Caracas Observatory.
1949 Harding Worden Meter 10c g 978.0399*
2. Cartographia Nacional, Commander Shelton's
Pendulum station in basement.
1949 Harding Worden Meter 10c g 978.0037*
3. Loma Quintana Station No. Tl X 67, 1946.
1949 Harding Worden Meter 10c g 978.0311*
4. Maiquetia Airport, just inside door of outgoing
baggage room.
1949 Harding Worden Meter 10c g 978.2490*

Maracaibo Zulia
Airport, about 100 yards west of main hangar on
north edge of Pan American taxi ramp.
1949 Harding Worden Meter 10c g 978.2009*

Maturin Monagas
Airport, in northeast corner of PAA garage
north of Customs and Operations terminal.
1949 Harding Worden Meter 10c g 978.0132*

V-1 Antimano Miranda
In city Plaza at BM #D 46, 1941.
1949 Harding Worden Meter 10c g 978.0500 *

V-2 Sebastopol Bridge Miranda
(Station A) south end against bluff.
1949 Harding Worden Meter 10c g 977.9977*

V-3 Los Teques Miranda
In Plaza Bolivar at BM #13, 1947.
1949 Harding Worden Meter 10c g 977.9762*

V-4 Boqueron Miranda
(Station B) on cement water tank at Ocampo Road
junction.
1949 Harding Worden Meter 10c g 977.9914*

Venezuela (continued)

- V-5 Guayas River Bridge Aragua
(Station C) upstream (west) side of bridge at
end of steel girders.
1949 Harding Worden Meter 10c g 978.0923*
1949 Harding Worden Meter 10c g 978.0922*
- V-6 Loma El Hierro (Point) Aragua
(Station D) on cement culvert.
1949 Harding Worden Meter 10c g 977.9569*
- V-7 (Station E) Aragua
2.9 miles along highway north of Station D,
just over crest of mountain.
1949 Harding Worden Meter 10c g 977.9341*
- V-8 (Station F) Aragua
First flat wide spot in road and just west of
creek.
1949 Harding Worden Meter 10c g 978.0179*
- V-9 (Station G) Aragua
50 yards downhill from house, on cement culvert.
1949 Harding Worden Meter 10c g 977.9947*
- V-10 (Station H) Aragua
On flood plain by right angle turn in palm trees
and on cement culvert.
1949 Harding Worden Meter 10c g 978.0896*
- V-11 Tejerias Aragua
Plaza BM #A-6, 1942.
1949 Harding Worden Meter 10c g 978.0847*
- V-12 El Consejo Aragua
Plaza BM #67, 1942.
1949 Harding Worden Meter 10c g 978.0681*
- V-13 La Victoria Aragua
Plaza BM # A-68, 1942.
1949 Harding Worden Meter 10c g 978.0612*
- V-14 San Mateo Aragua
Plaza BM #A-71, 1942.
1949 Harding Worden Meter 10c g 978.0678*
- V-15 Cagua Aragua
Plaza BM #A-26, 1943.
1949 Harding Worden Meter 10c g 978.0678*

Venezuela (continued)

- V-16 Guasupito Aragua
3.9 miles south of Cagua on highway at BM #A121/JL, 1946.
1949 Harding Worden Meter 10c g 978.0757*
- V-17 Aragua
7.3 miles south of Cagua at BM #A-120/JL, 1946.
1949 Harding Worden Meter 10c g 978.0713*
- V-18 Villa de Cura Aragua
Plaza Miranda at BM #A-118/JL, 1946.
1949 Harding Worden Meter 10c g 978.0664*
- V-19 (Station I) Aragua
East end of bridge crossing quebrada La Guarita, 4.8 miles from Villa de Cura.
1949 Harding Worden Meter 10c g 978.0861*
- V-20 (Station J) Guarico
East end of bridge over Rio Guarico, 10.8 miles from Villa de Cura.
1949 Harding Worden Meter 10c g 978.0924*
- V-21 La Puerta Guarico
(Station K) about two miles north of San Juan de los Morros.
1949 Harding Worden Meter 10c g 978.0913*
- V-22 Parapara Guarico
(Station L) on sidewalk across from telegraph station.
1949 Harding Worden Meter 10c g 978.1382*
- V-23 (Station M) Guarico
On north end of culvert about 8.5 miles north of Parapara.
1949 Harding Worden Meter 10c g 978.1155*
- V-24 San Juan de los Morros Guarico
In city Plaza at BM #G-113/JL, 1946.
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- V-25 (Station N) Guarico
At east end of bridge crossing Rio Guarico about six miles east of San Juan de los Morros.
1949 Harding Worden Meter 10c g 978.0953*

Venezuela (continued)

- V-26 San Sebastian Miranda
In city Plaza at BM #A-108 JL, 1946.
1949 Harding Worden Meter 10c g 978.1020*
- V-27 (Station O) Miranda
On north side of Rio Suato ten miles east of
San Sebastian.
1949 Harding Worden Meter 10c g 978.1071*
- V-28 Pardillal Miranda
At junction of San Sebastian and Camatagua roads
at BM #A-104/JL, 1946.
1949 Harding Worden Meter 10c g 978.0996*
- V-29 San Casimiro Miranda
In Plaza Bolivar at BM #A-102 JL, 1946.
1949 Harding Worden Meter 10c g 978.0967*
- V-30 Miranda
Mountain crest, about six miles east of San
Casimiro at BM #E-100 JL, 1946.
1949 Harding Worden Meter 10c g 978.0664*
- V-31 Miranda
About 12 miles east of San Casimiro at BM #E-90 JL,
1945.
1949 Harding Worden Meter 10c g 978.1165*
- V-32 Cua Miranda
In Plaza Bolivar at BM # E-96 JL, 1945.
1949 Harding Worden Meter 10c g 978.1510*
- V-33 (Station P) Miranda
At junction of roads to Cua and Cumare del Tuy.
1949 Harding Worden Meter 10c g 978.1564*
- V-34 Charallave Miranda
(Station Q) under sign at north end of bridge.
1949 Harding Worden Meter 10c g 978.1578*
- V-35 (Station R) Miranda
On culvert at intersection of El Valle road
and road to Paracotos.
1949 Harding Worden Meter 10c g 978.0495*

Venezuela (continued)

V-36	(Station S)	Miranda				
		At southwest corner of intersection of El Valle				
		road and road to San Diego.				
	1949	Harding	Worden Meter 10c	g	977.9626*	
	1949	Harding	Worden Meter 10c	g	977.9627*	
V-37	Carrizales	Miranda				
		(Station T) in center of city plaza.				
	1949	Harding	Worden Meter 10c	g	977.9503*	
V-38	San Diego	Miranda				
		(Station U) at base of statue in center of plaza.				
	1949	Harding	Worden Meter 10c	g	977.9485*	

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